PTO-1390 (06-13)
Approved for use through 6/30/2013. OMB 0651-0021
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371

Attorney Docket No.	U.S. Application No. (if known, see 37 CFR 1.5)
P37056A US (37659.00060)	

International Application No.	International Filing Date	Priority Date Claimed
PCT/US2014/072380	24 December 2014	24 December 2013

Title of Invention
SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

First Named Inventor
William LeFebvre

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☑ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). NOTE: The express request under 35 U.S.C. 371(f) will not be effective unless the requirements under 35 U.S.C. 371(c)(1), (2), and (4) for payment of the basic national fee, copy of the International Application and English translation thereof (if required), and the oath or declaration of the inventor(s) have been received.
2. ☑ A copy of the International Application (35 U.S.C. 371(c)(2)) is attached hereto (not required if the International Application was previously communicated by the International Bureau or was filed in the United States Receiving Office (RO/US)).
3. An English language translation of the International Application (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
4. An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4))
   a. ☑ is attached.
   b. ☐ was previously filed in the international phase under PCT Rule 4.17(iv).

Items 5 to 8 below concern amendments made in the international phase.

PCT Article 19 and 34 amendments

5. ☐ Amendments to the claims under PCT Article 19 are attached (not required if communicated by the International Bureau) (35 U.S.C. 371(c)(3)).
6. ☐ English translation of the PCT Article 19 amendment is attached (35 U.S.C. 371(c)(3)).
7. ☐ English translation of annexes (Article 19 and/or 34 amendments only) of the International Preliminary Examination Report is attached (35 U.S.C. 371(c)(5)).

Cancellation of amendments made in the international phase

8a. ☐ Do not enter the amendment made in the international phase under PCT Article 19.

8b. ☐ Do not enter the amendment made in the international phase under PCT Article 34.

NOTE: A proper amendment made in English under Article 19 or 34 will be entered in the U.S. national phase application absent a clear instruction from applicant not to enter the amendment(s).

The following items 9 to 17 concern a document(s) or information included.

9. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
10. ☑ A preliminary amendment.
11. ☑ An Application Data Sheet under 37 CFR 1.76.
12. ☐ A substitute specification. NOTE: A substitute specification cannot include claims. See 37 CFR 1.125(b).
13. ☑ A power of attorney and/or change of address letter.
14. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.3 and 37 CFR 1.821-1.825.
15. ☑ Assignment papers *(cover sheet and document(s))*. Name of Assignee: Amsted Rail Company, Inc.
16. ☑ 37 CFR 3.73(c) Statement *(when there is an Assignee)*.

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

U.S. APPLN. No. (if known – see 37 CFR 1.5)	INTERNATIONAL APPLICATION No.	ATTORNEY DOCKET No.
	PCT/US2014/072380	P37056A US (37659.00060)

17. ☑ Other items or information:

The Assignments and Statement Under 37 CFR 3.73(c) are included to facilitate acceptance of the Power of Attorney. The Assignments will be recorded separately on even date by Applicant's representative.

The following fees have been submitted.	CALCULATIONS	PTO USE ONLY
18. ☑ Basic national fee (37 CFR 1.492(a)) **$280**	$ 280	
19. ☑ Examination fee (37 CFR 1.492(c)) If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) ..... **$0** All other situations **$720**	$ 720	
20. ☑ Search fee (37 CFR 1.492(b)) If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) ..... **$0** Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority .....**$120** International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB .....**$480** All other situations **$600**	$ 120	
TOTAL OF 18, 19, and 20 =	$ 1120	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing in compliance with 37 CFR 1.821(c) or (e) in an electronic medium or computer program listing in an electronic medium) (37 CFR 1.492(j)). Fee for each additional 50 sheets of paper or fraction thereof **$400**		

Total Sheets	Extra Sheets	Number of each addition 50 or fraction thereof (round **up** to a whole number)	RATE	
- 100 =	/ 50 =		x **$400**	$

Surcharge of **$140.00** for furnishing any of the search fee, examination fee, or the oath or declaration after the date of commencement of the national stage (37 CFR 1.492(h)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	31 - 20 =	11	x **$80**	$ 880	
Independent claims	4 - 3 =	1	x **$420**	$ 420	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			**+ $780**	$	
Processing fee of **$140.00** for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)). +				$	
TOTAL OF ABOVE CALCULATIONS =				$ 1300	
☐ **Applicant asserts small entity status.** See 37 CFR 1.27. Fees above are reduced by ½.					
☐ **Applicant certifies micro entity status.** See 37 CFR 1.29. Fees above are reduced by ¾. Applicant must attach form PTO/SB/15A or B or equivalent.					
TOTAL NATIONAL FEE =				$ 2420	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property. +				$	
TOTAL FEES ENCLOSED =				$ 2420	
				Amount to be refunded:	$
				Amount to be charged:	$

a. ☐ A check in the amount of $_____ to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees.

c. ☑ The Director is hereby authorized to charge additional fees which may be required, or credit any overpayment, to Deposit Account No. 501943 as follows:

i. ☑ any required fee.

ii. ☐ any required fee except for excess claims fees required under 37 CFR 1.492(d) and (e) and multiple dependent claim fee required under 37 CFR 1.492(f).

d. ☑ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038. The PTO-2038 should only be mailed or faxed to the USPTO. However, when paying the basic national fee, the PTO-2038 may NOT be faxed to the USPTO.

ADVISORY: If filing by EFS-Web, do **NOT** attach the PTO-2038 form as a PDF along with your EFS-Web submission. Please be advised that this is **not** recommended and by doing so your **credit card information may be displayed via PAIR**. To protect your information, it is recommended to pay fees online by using the electronic payment method.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File)Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013, and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

NOTE 1: By providing this statement under 37 CFR 1.55 or 1.78, **this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA**.

NOTE 2: A U.S. national stage application may not claim priority to the international application of which it is the national phase. The filing date of a U.S. national stage application is the international filing date. See 35 U.S.C. 363.

Correspondence Address

☑ The address associated with Customer Number: 29880 **OR** ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone			
Email					

Signature	/gah/	Date	24 June 2016
Name (Print/Type)	Gary A. Hecht	Registration No. (Attorney/Agent)	36826

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number PCT/US2014/072380 filed on December 24, 2014.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

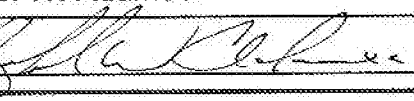
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Rachel W. Adamec Date (Optional) 16 Sept 2015

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number PCT/US2014/072380

filed on December 24, 2014.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: William D. LeFebvre Date (Optional): _____

Signature: _____

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number PCT/US2014/072380

filed on December 24, 2014.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

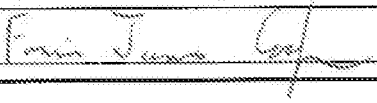
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Francis James Cooper Date (Optional): _____

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number PCT/US2014/072380 filed on December 24, 2014.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Andrew H. Martin Date (Optional): _____

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNITED STATES DESIGNATED/ELECTED OFFICE

In re application of: Lefebvre et al.	Group Art Unit: Unknown
International Application: **PCT/US2014/072380**	Examiner: Unknown
Int'l Filing Date: December 24, 2014	Attorney Docket: P37056A US (37659.00060)
For: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	Customer No. 29880

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT
NATIONAL PHASE ENTRY

Sir:

Please amend the above-identified application as follows:

Amendments to the claims are reflected in the listings of claims which begin on page 2 of this paper.

Remarks begin on page 16.

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1 (currently amended). A system for detecting operational anomalies on a train consist or railcar comprising:

(a) one or more communication management units mounted on one or more railcars; and

(b) one or more sensors located on said one or more railcars for sensing an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units; ~~and~~

~~c)~~ wherein said communication management units perform the functions of:

(i) collecting data regarding said one or more railcar operational parameters;

(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

2 (currently amended). The system of claim 1 further comprising one or more wireless sensor nodes in communication with one of said communication

management units, said one or more sensors forming part of said one or more wireless sensor nodes;

wherein each of said wireless sensor nodes performs the functions of:

collecting data from one or more sensors;

comparing said data against one or more rules; and

sending a message to said communication management unit when at least one of said rules is satisfied; and

wherein said communication management unit and said wireless sensor nodes form a railcar-based wireless mesh network, said railcar-based mesh network being controlled by said communication management unit.

3 (canceled).

4 (original). The system of claim 2 wherein each of said wireless sensor nodes performs the functions of:

a) collecting data from one or more sensors; and

b) periodically sending said collected data to said communication management unit.

5 (currently amended). The system of claim ~~3~~ 2 wherein said one or more rules are numerical thresholds which, when exceeded by said collected data, cause an alert message to be sent to said communication management unit.

6 (canceled).

7 (canceled).

8 (currently amended). The system of claim [[5]] 2 wherein said communication management unit, upon receiving an alert message from one of said wireless sensor nodes, performs the functions of:

(a) waiting to see if similar messages are received from one or more other wireless sensor nodes within a predetermined period of time and concluding that an actual event has occurred if said similar messages are received; and

(b) communicating a message reporting the occurrence of said actual event to a remote receiver.

9 (currently amended). The system of claim 4 wherein said communication management unit, upon receiving said periodically sent data, performs the functions of:

(a) storing said data in a data store;

(b) analyzing said stored data for trends; and

(c) generating a report when trends of interest are detected.

10 (currently amended). The system of claim 1 further comprising a powered wireless gateway controlling a train-based wireless mesh network that includes said powered wireless gateway and a plurality of said communication management units.

~~8 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to see if acceleration thresholds representing one or more of the following have been exceeded: wheel damage, vertical impacts or derailment.~~

11 (currently amended). The system of claim 1 wherein at least one of said communication management units includes at least one of said sensors. ~~8 wherein said wireless sensor node is mounted on the body of a railcar and further wherein said data is analyzed to see if acceleration thresholds representing one or more of the following have been exceeded: vertical hunting, lateral hunting, vertical extreme vehicle dynamics, lateral extreme vehicle dynamics, or longitudinal impacts.~~

12 (currently amended). The system of claim ~~7~~ 10 wherein said powered wireless gateway serves as said remote receiver.~~wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to see if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded.~~

13 (currently amended) . The system of claim 1 wherein said remote receiver is located off-train. ~~8 wherein said communication management unit confirms that a derailment event has occurred when derail messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.~~

14 (original). The system of claim 8 wherein said communication management unit confirms that vertical hunting is occurring when vertical hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

15 (original). The system of claim 14 wherein said communication management unit determines that a body bounce event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate in phase accelerations were detected.

16 (original). The system of claim 14 wherein said communication management unit determines that a body pitch event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate out of phase accelerations were detected.

17 (original). The system of claim 8 wherein said communication management unit confirms that a lateral extreme vehicle dynamic event has occurred when lateral extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

18 (original). The system of claim 8 wherein said communication management unit confirms that a vertical extreme vehicle dynamic event has occurred when

vertical extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

19 (original). The system of claim 8 wherein said communication management unit confirms that lateral hunting is occurring when lateral hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

20 (original). The system of claim 19 wherein said communication management unit determines that a body yaw event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate out of phase accelerations were detected.

21 (original). The system of claim 19 wherein said communication management unit determines that a body roll event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate in phase accelerations were detected.

22 (canceled).

23 (canceled).

24 (canceled).

25 (canceled).

26 (canceled).

27 (currently amended). The system of claim ~~3~~ 2 wherein said communication management unit can instruct each wireless sensor node to enable or disable the checking of individual rules by sending a message to said wireless sensor node.

28 (original). The system of claim 4 wherein said communication management unit can instruct each wireless sensor node to enable or disable the periodic sending of data by sending a message to said wireless sensor node.

29 (canceled).

30 (canceled).

31 (original). The system of claim 1 further comprising a powered wireless gateway controlling a train-based network that includes said powered wireless gateway and a plurality of said communication management units.

32 (canceled).

33 (canceled).

34 (canceled).

35 (currently amended). A method for detecting operational anomalies on a train consist or railcar comprising the steps of:

(a) collecting data regarding said one or more railcar operational parameters;

(b) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

(c) communicating a message to a remote receiver when said trend or event is detected.

36 (currently amended). The method of claim 35 wherein steps (a) – (c) are performed by a communication management unit located on a railcar in said train consist;

wherein said data is collected from one or more wireless sensor nodes on said railcar, said wireless sensor nodes being in communication with said communication management unit; and

wherein said communication management unit and said one or more wireless sensor nodes form a railcar-based mesh network.

37 (canceled).

38 (canceled).

39 (currently amended). The method of claim ~~37~~ 36 wherein said wireless sensor nodes each perform the functions of:

(a) collecting data from one or more sensors;

(b) comparing said data against one or more rules; and

(c) sending a message to said communication management unit when at least one of said rules is satisfied; and

wherein said one or more rules causes data collected from some sensors to be periodically sent to said communication management unit.

40 (canceled).

41 (canceled).

42 (currently amended). The method of claim ~~37~~ 39 wherein said communication management unit coordinates messages from two or more wireless sensor nodes to confirm that an event has occurred.

43 (canceled).

44 (canceled).

45 (currently amended). The method of claim 36 wherein multiple railcars in said train consist are configured with a communication management unit and further wherein all communication management units on said train consist are configured in a train-based wireless mesh network controlled by a powered wireless gateway.

46 (canceled).

47 (canceled).

48 (canceled).

49 (currently amended). The system of claim [[3]] 2 wherein one of said wireless sensor nodes comprises:

a) a protective housing;

b) said one or more sensors being mounted within said protective housing and includes a sensor to measure accelerations;

c) a communication capability, for communicating with said communication management unit; ~~and~~

d) a microprocessor, executing firmware to control the operation of said wireless sensor node; and

e) a mechanical filter which includes a resilient material selected to filter out undesirable accelerations, said mechanical filter disposed to remove said undesirable accelerations before said undesirable accelerations reach said accelerometer.

50 (canceled).

51 (canceled).

52 (currently amended). The system of claim [[50]] 2 wherein one of said wireless sensor nodes ~~further~~ comprises:

a) a protective housing;

b) said one or more sensors being mounted within said protective housing and includes a sensor to measure accelerations;

c) a communication capability, for communicating with said communication management unit; ~~and~~

d) a microprocessor, executing firmware to control the operation of said wireless sensor node; and

e) potting material disposed within said housing, said potting material used to tune said wireless sensor node by absorbing undesirable accelerations.

53 (canceled).

54 (canceled).

55 (canceled).

56 (currently amended). A system for detecting operational anomalies on a train consist or railcar comprising:

(a) a train-based mesh network comprising a powered wireless gateway and one or more communication management units located on one or more railcars in said train consist;

(b) one or more railcar-based mesh networks each comprising at least said one or more communication management units, each arranged in a mesh network configuration with one or more wireless sensor nodes;

(c) a distributed complex event processing engine distributed across said wireless sensor nodes, said communication management units and said powered wireless gateway, said distributed complex event processing engine detecting anomalous operating conditions on said train consist via data gathered by sensors controlled by said wireless sensor nodes and propagated upwards through said system.

57 (canceled).

58 (canceled).

59 (canceled).

60 (amended). A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

~~a.~~(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;

~~b.~~(b) at least two sensors located on ~~the~~ said railcar for sensing operational parameters of the railcar, said sensors being in communication with said communication management unit~~CMU~~;

~~c.~~ wherein said ~~CMU~~ communication management unit performs the following functions:

(i) receiving data from said sensors;

(ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and

(iii) communicating a message to a remote receiver when an anomaly is detected.

61 (~~currently amended~~). The system of claim 60,

wherein said sensors comprise accelerometers positioned at different locations of the railcar,

~~and~~ wherein said step of drawing inferences comprises the comparison of data from two or more of said accelerometers,

wherein said accelerometers are positioned on the railcar to provide data for carrying out one or more of the following functions:

i) compare accelerations from one railcar wheel with that of another railcar wheel on the same axle but opposite side of the railcar,

ii) compare accelerations from one railcar wheel with that of at least one other wheel on the same side of said railcar, and

iii) compare accelerations from one railcar wheel with that of at least one other railcar wheel on the same side of said one railcar wheel and which other wheel is on another railcar of the same train consist.

62 (canceled).

63 (canceled).

64 (canceled).

65 (canceled).

Remarks

The filing fees should be based on the claims as amended herein. These amendments are made without prejudice to reinstating the canceled claims.

Respectfully submitted,

Date: 06/23/2016

/gah/

Gary A. Hecht
Reg. No. 36,826
Fox Rothschild LLP
2000 Market St
20th Floor
Philadelphia, PA 19103
Telephone: 215-299-2000
Facsimile: 610-299-2150

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	William		LeFebvre	

Residence Information (Select One) ● US Residency ○ Non US Residency ○ Active US Military Service

City	State/Province	Country of Residence
West Chester	PA	US

Mailing Address of Inventor:

Address 1	1145 Saint Finegan Drive
Address 2	

City	State/Province	Postal Code	Country
West Chester	PA	19382	

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Andrew		Martin	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	State/Province	Country of Residence
West Chester	PA	US

Mailing Address of Inventor:

Address 1	926 Pineview Drive
Address 2	

City	State/Province	Postal Code	Country
West Chester	PA	19380	US

Inventor 3 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Francis	James	COOPER	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

City	Downingtown	State/Province	PA	Country of Residence	US

Mailing Address of Inventor:

Address 1	1581 General Patton Drive
Address 2	

City	Downingtown	State/Province	PA
Postal Code	19335	Country	US

Inventor 4 — Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Rachel	W.	ADAMEC	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Norristown	State/Province	PA	Country of Residence	US

Mailing Address of Inventor:

Address 1	602 Middleton Place
Address 2	

City	Norristown	State/Province	PA
Postal Code	19403	Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. — Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	29880		
Email Address	ipdocket@foxrothschild.com	Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS		
Attorney Docket Number	P37056A US (37659.00060)	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	14	Suggested Figure for Publication (if any)	1

Filing By Reference :

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	29880		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the application number blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	a 371 of international	PCT/US2014/072380	2014-12-24
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
PCT/US2014/072380	Claims benefit of provisional	61920700	2013-12-24

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Authorization to Permit Access:

☐ Authorization to Permit Access to the Instant Application by the Participating Offices

PTO/AIA/14 (07-14)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date o f filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

● Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here. ☒

Organization Name	Amsted Rail Company, Inc.

Mailing Address Information For Applicant:

Address 1	311 South Wacker Drive, Suite 5300		
Address 2			
City	Chicago	**State/Province**	IL
Country	US	Postal Code	60606
Phone Number		Fax Number	

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

Email Address	

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not subsitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication . An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☒

Organization Name	Amsted Rail Company, Inc.

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1	311 South Wacker Drive, Suite 5300		
Address 2			
City	Chicago	**State/Province**	IL
Country i	US	Postal Code	60606
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

Remove

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Signature	/gah/			Date (YYYY-MM-DD)	2016-06-24
First Name	Gary	Last Name	Hecht	Registration Number	36826

Additional Signature may be generated within this form by selecting the Add button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056A US (37659.00060)
	Application Number	
Title of Invention	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS	

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent C o o p eration Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 July 2015 (02.07.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/100425 A1

(51) International Patent Classification:
B61L 15/00 (2006.01)

(21) International Application Number:
PCT/US2014/072380

(22) International Filing Date:
24 December 2014 (24.12.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/920,700 24 December 2013 (24.12.2013) US

(71) Applicant: **AMSTED RAIL COMPANY, INC.** [US/US]; 311 South Wacker Drive, Suite 5300, Chicago, IL 60606 (US).

(72) Inventors: **LEFEBVRE, William**; 1145 Saint Finegan Drive, West Chester, PA 19382 (US). **MARTIN, Andrew, H.**; 926 Pine View Drive, West Chester, PA 19380 (US). **COOPER, Francis, James**; 1581 General Patton Drive, Downington, PA 19335 (US). **ADAMEC, Rachel, W.**; 602 Middleton Place, Norristown, PA 19403 (US).

(74) Agents: **HECHT, Gary, A.** et al.; Fox Rothschild LLP, 997 Lenox Drive, Building 3, Lawrenceville, NJ 08648-2311 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

(57) Abstract: A system for monitoring railcar and tram consist operational parameters and detecting anomalies in the operation and condition thereof using sensors to feed data to a distributive complex event processing engine.

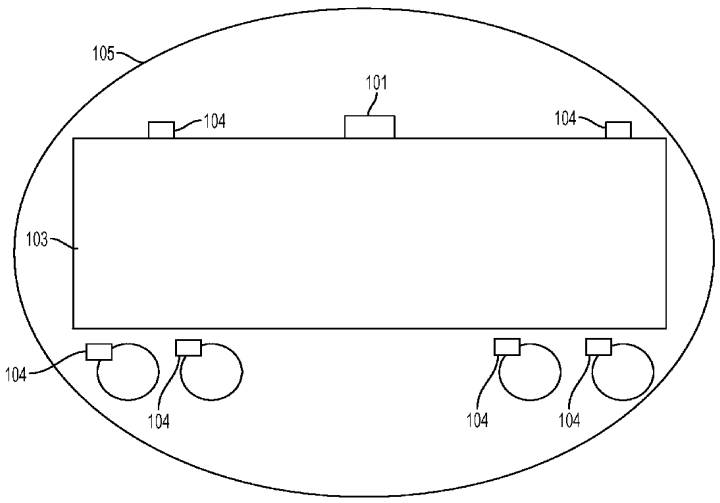


FIG. 1

WO 2015/100425 A1

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

Related Applications

[0001] The application claims the benefit of U.S. provisional application 61/920,700, filed December 24, 2013, the entirety of which is hereby incorporated herein by reference.

Field of the Invention

[0002] The present invention relates to the field of railcar and train safety management, and is specifically directed to a system and method for continuously collecting and analyzing operational parameters of railcars and train consists to detect anomalous operating conditions.

Background of the Invention

[0003] Current prior art monitoring of bearings and wheel to rail interactions on train consists has been managed primarily through the use of wayside detectors located throughout the rail system, which includes detectors for monitoring the temperature of railcar wheel bearings, and wheel impact load detectors which identify damaged wheels by monitoring impacts of wheels on the rails. These detectors are installed at fixed points in the rail network.

[0004] Since their introduction, these methods have provided railroad operators with information to improve railcar and train consist performance. However, these detectors lack the benefits of a wireless network capable of transmitting information and data regarding operational anomalies, such as when a railcar derails, the condition of the bearings and wheels when not in range of detectors, and wheel damage. Further, these prior methods do not provide a mechanism to continuously monitor assets at any location in the rail network.

[0005] Wheel damage in the railroad industry is responsible for significant maintenance costs related to the railcar wheels, railcar body, railcar components, rail tracks and rail ties. Wheels that are slid flat have an uneven section on the wheel where it comes into contact with the rail. As the wheel rotates this section creates an abnormal impact pattern, which can cause further damage to the wheel, damage to the railcar and damage to the rail and track structure.

[0006] Presently, however, there is no reliable system for continuously monitoring the temperature of wheel bearings or wheel to rail interactions where a wheel impact load detector is not installed on a section of rail or in the area between detectors. Accordingly, it is desirable to provide a system and method for the real-time, on-board monitoring of various operational parameters of a railcar and/or train consists, and for analyzing the readings in real time to predict or timely detect anomalous operational conditions.

Summary of the Invention

[0007] The system presented herein addresses the deficiencies in prior art monitoring systems for railcars and train consists. The system consists of a hierarchical arrangement of components which provide a distributed data analysis capability that is capable of detecting operational anomalies at various levels of the hierarchy, and which provides for the flow of data, events and alerts to a central point.

[0008] At the lowest level of the hierarchy, each railcar is equipped with multiple wireless sensor nodes (referred to in the singular as a "WSN"), which are arranged in a mesh network controlled by a communication management unit ("CMU"), usually on the same railcar, referred to herein as a railcar-based mesh network. The wireless sensor nodes collect data regarding various operational parameters of the railcar and are capable of detecting certain anomalies based on the collected data. When anomalous operational data is

detected, an alert may be raised and the data may be communicated to the communication management unit located on the railcar. Although mesh networks are used in the embodiments illustrated herein, other types of network topologies may be used.

[0009] The communication management units located on each railcar are also arranged in a mesh network which is controlled by a powered wireless gateway, typically located in the locomotive. This is referred to herein as a train-based mesh network. Again, although mesh networks are used in the embodiments illustrated herein, other types of network topologies may be used.

[0010] The train-based wireless mesh network communicates the length of the train consist and delivers information about the railcars to a powered host or control point, such as the locomotive or an asset with access to a power source and to a railroad remote operations center.

Brief Description of the Drawings

[0011] The present invention will be more fully and completely understood from a reading of the Detailed Description of the Invention in conjunction with the drawings, in which:

[0012] Figure 1 is a schematic of a railcar 103 equipped with a communication management unit (CMU) 101 and a plurality of wireless sensor nodes (WSNs) 104 installed thereon, forming a railcar-based mesh network 105.

[0013] Figure 2 is a schematic of a train-based mesh network with two railcars 103 each equipped with a CMU 101 and multiple WSNs 104, a railcar 103 equipped with just a CMU 101 (no WSNs), a railcar 103 without a CMU or WSN, and a powered wireless gateway device 102 installed on a locomotive 108.

[0014] Figure 3 shows a train-based mesh network 107 and various means of communicating data off-train.

[0015] Figure 4 is an exploded view of a first variety of WSN 104 which can be used, for example, for monitoring bearing temperature and wheel acceleration.

[0016] Figure 5 is an exploded view of a second variety of WSN 104 which can be used, for example, for monitoring railcar body acceleration, and which can include a temperature sensor (not shown) for monitoring temperature.

[0017] Figure 6 shows the WSN 104 of Figure 4 installed on a railcar wheel bearing fitting 111.

[0018] Figure 7 is a flow chart showing the conditions under which longitudinal impact acceleration event processing is enabled and disabled.

[0019] Figure 8 is a flow chart showing the conditions under which vertical and lateral hunting acceleration event processing is enabled and disabled.

[0020] Figure 9 is a flow chart showing the conditions under which derailment monitoring event processing is enable and disabled.

[0021] Figure 10 is a flow chart showing the conditions under which wheel damage or vertical impact event processing is enabled and disabled.

[0022] Figure 11 is a flow chart showing the conditions under which bearing temperature event processing is enabled and disabled.

[0023] Figure 12 is an architectural diagram showing a generalized model for implementation of the data analysis portion of a WSN 104.

[0024] Figure 13 is a specific implementation of the model shown in Figure 12 directed to detection of railcar body events.

[0025] Figure 14 is another specific implementation of the model shown in Figure 12, this one directed to detection of wheel bearing events.

Detailed Description of the Invention

[0026] A **railcar**, as the term is used herein, may be a single railcar 103, see Fig. 1, or may consist of two or more railcars 103 which are permanently connected, often referred to by those of skill in the art as a "tandem pair", "three-pack", "five-pack", etc.

[0027] A **train consist**, shown in the drawings as reference number 109, see Fig. 2, is defined as a connected group of railcars 103 and locomotives 108.

[0028] A **communication management unit** ("CMU"), shown in the drawings as reference number 101, is preferably located on a railcar 103 and controls the railcar-based mesh network 105 (defined below) overlaid on railcar 103 which may consist of one or more individual railcars 103 which are permanently connected together. The CMU 101 hardware preferably includes a processor, a power source (e.g. a battery, solar cell, energy harvester, or internal power-generating capability), a global navigation satellite system (GNSS) device such as a global positioning system ("GPS") receiver, Wi-Fi, satellite, and/or cellular capability, a wireless communications capability for maintaining the railcar-based mesh network 105, wireless communication with a train-based mesh network 107 and, optionally, one or more sensors, including, but not limited to, an accelerometer 404, gyroscope, or temperature sensor 406.

[0029] The CMU 101 supports one or more WSNs 104 (defined below) in a mesh network configuration using open standard protocols, such as the IEEE 2.4 GHz 802.15.4 radio standard. Additionally, the CMU 101 is also a member of a train-based mesh network 107, which consists of the CMUs 101 from all enabled railcars 103 in the train consist 109, controlled by a powered wireless gateway 102, typically located on a locomotive 108. The CMU 101 thus supports four functions: 1) to manage a low-power railcar-based mesh network 105 overlaid on a railcar 103; 2) to consolidate data from one or more WSNs 104 in the railcar-based mesh network 105 and to apply logic to the data gathered to generate warning alerts to a host such as a locomotive 108 or remote railroad operations center 120; 3) to support built-in sensors, such as an accelerometer 404, within the CMU 101 to monitor specific attributes of the railcar 103 such as location, speed, and accelerations, and to provide an analysis of this data to generate alerts; and 4) to support bi-directional

communication upstream to the host or control point, such as a locomotive 108 and/or an off-train monitoring and remote railroad operations center 120, and downstream to one or more WSNs 104, located on the railcar 103. CMUs 101 may communicate wirelessly to a powered wireless gateway (PWG 102 as defined below) in a mesh network configuration, or may be configured to communicate through a wired connection, for example, through the ECP (electronically controlled pneumatic) brake system. Those skilled in the art will appreciate that GPS is just one form of a global navigation satellite system (GNSS). Other types of GNSS include GLONASS and BeiDou with others in development. Accordingly, although GPS is used in the embodiments described herein, any type of GNSS system or devices may be used.

[0030] The CMU 101 is capable of receiving data and/or alarms from one or more WSNs 104 and is capable drawing inferences from this data or alarms regarding the performance of railcar 103, and of transmitting data and alarm information to a remote receiver. The CMU 101 is preferably a single unit that would serve as a communications link to other locations, such as a powered wireless gateway 102 (preferably located in locomotive 108), or a remote railroad operations center 120, and have the capability of processing the data received. The CMU 101 also communicates with, controls and monitors WSNs 104 in the local railcar-based mesh network 105.

[0031] A **powered wireless gateway** ("PWG"), shown in the drawings as reference number 102 (see, e.g., Fig. 2), is preferably located on a locomotive 108 or elsewhere on a train consist 109 where there is a source of external power. It typically will include a processor; a GPS receiver; one or more sensors, including, but not limited to, an accelerometer 404, gyroscope, or temperature sensor 406; a satellite and or cellular communication system; local wireless transceiver (e.g. WiFi); an Ethernet port; a high capacity mesh network manager and other means of communication. The PWG 102 will have power supplied by the locomotive 108, if located on a powered asset, such as a locomotive 108, or will derive its power from another source, for example, from a solar power generator or from a high-capacity battery. The PWG 102 controls

a train-based mesh network 107 overlaid on a train consist 109, consisting of multiple CMUs 101 from each railcar 103 in a train consist 109.

[0032] The components and configuration of the PWG 102 are similar to that of a CMU 101, with the exception that the PWG 102 typically draws power from an external source, while the CMU 101 is self-powered. Additionally, the PWG 102 collects data and draws inferences regarding the performance of the train consist 109, and train-based mesh network 107, as opposed to CMUs 101, which draw inferences regarding the performance of individual railcars 103 and railcar-based mesh network 105 or 118.

[0033] A **railcar-based mesh network** shown in the drawings as reference number 105, see, e.g., Figs. 1 and 2, consists of a CMU 101 on a railcar 103, which is part of and manages a railcar-based mesh network 105 of a plurality of WSNs 104, each deployed, preferably on the same railcar 103.

[0034] A **wireless sensor node** ("WSN"), shown in the drawings as reference number 104, see, e.g., Figs. 1 and 2, is located on a railcar 103, and provides the functions of collecting data from internal sensors and analyzing the data collected from the sensors to determine if the data needs to be transmitted immediately, held for later transmission, or aggregated into an event or alert. The WSN 104 is used for sensing a parameter to be monitored (e.g. temperature of bearings or ambient air) or status (e.g., position of a hatch or hand brake). In a preferred embodiment, each WSN 104 is equipped with one or more accelerometers or gyroscopes and one or more temperature sensors. Examples of WSNs 104 are disclosed in published U.S. patent application 2013/0342362, the disclosure of which is hereby incorporated by reference herein. A typical WSN 104 is shown in exploded view in Figure 4 and Figure 5 and will now be explained in more detail.

[0035] With reference to Figure 4, an example of a first variety of WSN 104 is now described. The WSN 104 shown in Figure 4 is configured and tuned to detect certain kinds of acceleration and temperature events and is typically located on the wheel bearing fitting 111 of railcar 103, where it is likely to be subjected to various degrees of accelerations and where it can easily collect data regarding the temperature of the wheel bearing. The components of WSN 104 are contained in a housing 400 having an enclosure 400a and an

enclosure base 400b. Preferably, housing sections 400a, 400b are composed of a hard plastic resistant to environmental damage, such as a UV rated polymer, e.g., a polycarbonate/ABS blend, and when fully assembled is weatherproof. After the various components are installed within the housing as described below, a potting material (not shown) is provided through openings in the housing 400 to isolate, encapsulate and environmentally seal the components within. Such materials include epoxies, polyurethanes and silicone compounds. A flexible urethane suitable for electrical use and through which wireless signals can be transmitted is preferred. It has been found that the particular potting material used is also critical in the proper tuning of the WSN 104 to detect various types of accelerations. A potting material having a durometer of 59 Shore 00 is preferred.

[0036] Additionally, a mechanical filter 410 consisting of upper sections 410a and lower sections 410b further serve to mechanically filter high and low frequency types of accelerations that are considered noise and which are preferably removed from the signal of interest. Preferably, these components are composed respectively of silicone of durometer 70 Shore A (the upper filter sections 410a) and 30 Shore A (the lower filter sections 410b) in view of the differences of the surface areas of each section and this affect on the filtering characteristics.

[0037] In a preferred embodiment, each WSN 104 may have one or more accelerometers 404 and one or more temperature sensors 406. The tuning of WSN 104 is accomplished by a combination of the selection of the potting material, the durometer of upper and lower silicone mechanical filtering elements 410a and 410 b, and software filtering performed by software executing on a processor on main PC board 402a. The software filter used is a digital filter to decrease noise from unwanted acceleration frequencies and increase signals from acceleration frequencies of interest.

[0038] Temperature sensor 406, includes a heat transfer element which extends through an opening 406a in the enclosure base 400b, and opening 406b in the

filter section 410b. Preferably, the heat transfer element is a copper plug. This configuration is preferred for monitoring the surface temperature of the surface to which WSN 104 is attached, as the heat transfer element will make contact with the surface. In preferred embodiments of the invention, the temperature sensor 406 is a thermistor, thermocouple or silicone temperature sensor which are ideal for electronic circuits. In this embodiment, WSN 104 will be mounted to place the heat transfer element in thermal communication with the portion of the railcar 103 for which a temperature reading is desired. Additionally, the lower sections 410b of the mechanical filter are of a suitable thickness to create an air gap between the enclosure base 400b and the surface to which the WSN 104 is mounted. The lower sections 410b of the mechanical filter and the air gap create good thermal protection and low heat transfer from the surface to which the WSN 104 is mounted. This thermal protection keeps the electronics (all except for the temperature sensor 406) and the power source from being exposed to excess and potentially damaging heat. WSN 104 may also be equipped with additional temperature sensors (not shown) for sensing the ambient temperature.

[0039] In the preferred embodiment, self-taping screws 415 serve to attach WSN 104 to the railcar 103 and to hold upper and lower portion 410a and 410b of mechanical filter in place. Spacers 400c which fit within the screw openings 410c of the filter pads are chosen in length to control the amount of compression force on the filter sections 410a and 410b due to the tightening of the screws 415. Without the spacers 400c, the filtering characteristics of the filters could be changed due to compression from over tightening of the screws 415. The spacers are chosen from a suitably stiff material.

[0040] As one of ordinary skill would recognize, the configuration of WSNs 104 may vary with respect to the number and types of sensors. Virtually any type of sensor could be used, including, for example, a temperature sensor 406, a pressure sensor, a load cell, a strain gauge, a hall effect sensor, a vibration sensor, an accelerometer 404, a gyroscope, a displacement sensor, an

inductive sensor, a piezio resistive microphone or an ultrasonic sensor, depending on the specific operational parameter that is desired to be monitored. In addition, the sensor may be a type of switch, including, for example, reed switches and limit switches. An example of another type of mote sensor which uses a strain gauge, e.g. a hand brake monitor sensor, is described in U.S. patent publication 2012/0046811 (US Patent Application 12/861,713 filed August 23, 2010), the disclosure of which is hereby incorporated herein by reference.

[0041] Electrical circuitry is provided for the operation of WSN 104. The electrical circuitry includes the components and wiring to operate and/or receive and process the signals from the sensors. This can include, but is not limited to, analog and digital circuitry, CPUs, processors, circuit boards, memory, firmware, controllers, and other electrical items, as required to operate the accelerometers and temperature sensors 406 and to process the information as further described below.

[0042] In the illustrated embodiment in Figure 4, the circuitry includes a main board 402a which includes the communications circuitry, antennae and microprocessor and a daughter board 402b which includes circuitry to read the data from accelerometers 404 and temperature sensors 406. Main board 402a, daughter board 402b or the sensors may also include a processor executing firmware to provide intelligence sufficient to perform low-level analysis of the data, and may accept parameters from outside sources regarding when alarms should be raised, as described below.

[0043] Each WSN 104 also includes circuitry for wireless communications and a long-term power source 414(e.g. a battery, solar cell, energy harvester, or internal power-generating capability), preferably a military grade lithium-thionyl chloride battery. The circuitry also provides power conditioning and management functions and may include a feature to conserve battery life which keeps WSN 104 in a standby state and periodically wakes WSN 104 to deliver readings from the sensors.

[0044] Figure 5 shows an exploded view of a second variety of WSN 104, which is preferably mounted on the body of railcar 103. The variety of WSN 104 shown in Figure 5 is substantially identical to the variety shown in Figure 4 (and thus similar elements are identified with the same reference number), with the following differences. First, as this variety of WSN 104 will be mounted to the body of railcar 103, where it is likely to be subjected to more gentle accelerations, there is no need for the additional mechanical filtering provided by mechanical filters 410 of Figure 4. Thus, using four screws, two on each side, and given that this WSN is not exposed to the more violent accelerations of the other variety, the screws or bolts of this second variety can be smaller in diameter. Second, the illustrated embodiment does not include a temperature sensor 406, although one or more temperature sensors 406 may be provided with a heat transfer element, as discussed above for the first variety, extending through an opening in the housing to sense the desired temperature, e.g., the ambient temperature. Lastly, although this variety of WSN 104 includes an accelerometer 404 like the prior described WSN 104 of Fig. 4, it preferably will be programmed with different firmware to detect different types of acceleration events, as discussed below. As understood by one of ordinary skill, the WSNs of both varieties could also contain just a temperature sensor, although there would be no need for filtering as described with reference to Fig. 4.

[0045] Individual WSNs 104 are mounted on the areas of interest on a railcar 103. As an example, Figure 6 shows WSN 104 of the type shown in Fig. 4 mounted to a roller bearing fitting 111 of a railcar wheel bearing of a railcar 103. The unit may be attached using a thermally conductive epoxy adhesive between the heat transfer element and the roller bearing fitting 111 to ensure good heat transfer to the temperature sensor 406, and mechanical fasteners such as self-tapping screws 415 to hold WSN 104 in place.

System Operation

[0046] In broad terms, with reference to Figs. 1 and 2, the present invention provides a novel means for monitoring the performance and operation of a railcar 103 and train consist 109. This includes a plurality of sensors 104 deployed on the railcars 103 in the consist 109 for sensing various operational parameters of the railcar 103 and distributed complex event processing (DCEP) engine, which is a hierarchical system for collecting and analyzing the data and for communicating data, events and alerts to a final destination where they can be acted upon.

[0047] The DCEP is responsible for implementing the intelligence used to draw conclusions based on the data collected from WSNs 104, CMUs 101 and PWGs 102. Preferably, the data processing platform is distributed among all WSNs 104, CMUs 101 and the PWG 102 on the locomotive 108, as well as utilizing a cloud-based infrastructure optimized to work closely with train-based mesh networks 107, in conjunction with a variety of data streams from third-party providers or external sources.

[0048] With further reference to Fig. 1 of the drawings, a railcar-based mesh network is shown generally as reference number 105. Railcar-based mesh network 105 comprises a CMU 101 installed on a railcar 103 and one or more WSNs 104 installed on the same railcar 103. Railcar 103 may consist of one or more individual railcars 103, which are permanently connected together. The railcar-based mesh network 105 is a critical component in the processing of events and alerts on the railcar 103. CMU 101 and WSNs 104 work together to collect and analyze the data collected from sensors in the WSNs 104. CMU 101 controls the railcar-based mesh network 105 on railcars 103 and is able to configure one or a more WSNs 104 in a local mesh network to transmit, listen, or sleep at precise times, or to change the parameters under which WSNs 104 operate and detect events.

[0049] With further reference to Figure 2, a schematic of a train-based mesh network 107 is shown with two railcars 103 each equipped with a CMU 101 and multiple WSNs 104 installed near the wheel bearings of the railcar 103, a railcar 103 equipped with just a CMU 101 with no WSNs 104 attached, a railcar 103 without a CMU 101, and a PWG 102 installed on a locomotive 108. The CMU 101 and multiple WSNs 104 installed on railcars 103 form a

railcar-based mesh network 105 and communicate with the PWG 102 on a host or control point, such as a locomotive 108 or other asset, forming the train-based mesh network 107. The railcar-based mesh network for the railcar 103 having a CMU 101 only and no WSNs is designated 118.

[0050] If an alert or event condition is detected by a WSN 104, as described in more detail below, a message is forwarded by WSN 104 to CMU 101 for further analysis and action, for example, to confirm or coordinate alert or event conditions reported by one WSN 104 with other WSNs 104 in the railcar-based mesh network 105. If an alert or event is confirmed by CMU 101, a message is sent to PWG 102 installed on an asset, preferably with access to a power source and/or to an off train monitoring and remote railroad operations center 120.

[0051] CMU 101 on each railcar 103 is capable of supporting an optional global navigation satellite system (GNSS) sensor to determine location, direction and/or speed of railcar 103. This information can be used to determine whether or not WSNs 104 should be looking for certain types of events. For example, it is fruitless for a WSN 104 to attempt to detect derailments when the train consist 109 is stationary. Additionally, the PWG 102 can send instructions for the CMU 101 to start or stop looking for certain types of events. Additionally, CMU 101 on each railcar 103 is capable of using built-in sensors and/or managing a railcar-based mesh network 105 on the railcar 103 to generate messages that need to be sent to a host or control point, such as a locomotive 108.

Alert and Event Detection and Reporting

[0052] Each WSN 104 is capable of analyzing the data collected from its sensors in determining if the an event or alert message, as well as the data should be uploaded to the next higher level in the hierarchy, in this case CMU 101. With respect to accelerometers 404, each WSN 104 can be programmed with

multiple thresholds for peak and root mean square (RMS) level of magnitude values acceleration readings received from the one or more accelerometers 404. When one of the peak or RMS acceleration thresholds are exceeded, it is an indication of a possible event or alert condition, and a message is generated and sent to CMU 101 in the same railcar-based mesh network 105. The thresholds for each variety of WSN 104 may be dynamically programmed by commands either generated internally or received externally from CMU 101.

[0053] In the preferred embodiment, WSNs 104 are programmed with thresholds which indicate specific types of alerts or events. For the WSNs 104 mounted on wheel roller bearing fittings 111, these units may generate a possible derailment message, a vertical impact message or a wheel damage message depending upon the threshold which is exceeded. For WSNs 104 located on the body of railcar 103, examples of messages generated are longitudinal impact, extreme lateral railcar dynamics, extreme vertical railcar dynamics, vertical hunting and lateral hunting. In the illustrated embodiments, the WSNs 104 do not determine if each of the possible conditions actually exists. This determination is preferably made at the next level up of the hierarchy, at CMU 101, which utilizes the readings from multiple WSN 104 to make a determination that an actual event has occurred. As would be readily realized by one of skill in the art, different thresholds suggesting the occurrence of other types of events may be programmed into WSNs 104.

[0054] Regarding the temperature sensors 406 in each WSN 104, which are capable of sensing the temperature of the surface on which a WSN 104 is installed and/or the temperature of ambient air around the WSN 104, the temperature readings from each WSN are periodically reported to the CMU 101. The CMU 101 must coordinate the collecting of temperature data from all WSNs 104 in the railcar-based mesh network 105 and, as such, the period for reporting of temperatures, as well as the timing of the reporting of temperature data is programmed for each WSN 104 by CMU 101.

[0055] Each WSN 104 is able to make a determination of when to report data that may indicate a possible event or alarm condition to CMU 101. CMU 101 is able to collect such notifications from each WSN 104 under its control and coordinate the data to make a final determination as to whether or not an event or alarm condition actually exists. For example, in the preferred embodiment each wheel roller bearing fitting 111 in a railcar 103 will have a WSN 104 attached thereto to monitor accelerations and temperature. Thus, on a typical railcar 103 having two trucks (bogies), each with two axles, a total of eight WSNs 104 mounted to wheel roller bearing fitting 111 will be present. In addition, and also in accordance with a preferred embodiment, each railcar 103 will preferably have an additional WSN 104 located at each end of the railcar 103 attached directly to the railcar body. CMU 101 also may include acceleration, temperature or any other type of sensors and may replace one or more of the WSN 104s on the body of railcar 103 or may be supplemental to the set of WSN 104s that are installed on the body of railcar 103. The railcar-based mesh network 105 may include any combination of WSNs 104, including a configuration wherein the CMU 101 is the only component installed on the railcar 103. Additionally, CMU 101 may also monitor WSNs 104 installed on other railcars 103 such as in the case where railcar 103 may consist of one or more individual railcars 103 which are permanently connected together.

[0056] In the preferred embodiment, the logic in the CMU 101 is capable of analyzing both acceleration and temperature events received from each of the WSNs 104 under its control and determining if an alarm or event condition actually exists. It should be noted that acceleration events are independent of temperature events and the CMU 101 may be configured to either analyze only acceleration events, or to analyze only temperature events. Thus the CMU 101, and WSNs 104 under its control, form a distributed event processing engine which is capable of determining various types of events.

[0057] The acceleration events which CMU 101 is capable of detecting in the preferred embodiment will now be discussed in greater detail. It should be noted that when CMU 101 determines that an alarm or event has occurred, a message is sent to the next level in the hierarchy that is either to a PWG 102 located elsewhere on train consist 109 or off train consist 109 to a remote railroad operation center 120, depending upon the severity of the event and the need to immediately address the event, perhaps by altering the train consist's 109 operating condition. Examples of events that can be analyzed using the features described above are provided below.

[0058] Derailment – A derailment event is regarded as a high priority type of event and is an example of the type of events that can be analyzed by the illustrated embodiment. When a derail message is received from a WSN 104, the CMU 101 starts a derailment processing timer and also immediately generates a possible derailment message to the PWG 102. CMU 101 then waits to determine if any other WSNs 104 are generating derailment messages. If other WSNs 104 have generated derailment messages within a predetermined time interval, they are all presumed to have originated from the same physical event and a derailment message is generated and sent to PWG 102.

[0059] Figure 9 is a flow chart showing the conditions under which the derailment event is enabled or disabled. At 900, the system is initialized and, at 902, the system is placed in a waiting state in anticipation of the railcar 103 moving, wherein the derail event is disabled. It should be noted that derailment events are disabled when the railcar 103 is stationary. At 904, the system checks to see if the railcar 103 is stationary and, if it is, it returns to the waiting state at 902. If the railcar 103 is moving control moves to 906 where the derailment event is enabled. The derailment event is enabled by having CMU 101 send a message to each of the WSNs 104 under its control. At 908, the system is again placed in a waiting state; however, the derailment event is now enabled. At 910, the system queries as to whether a derailment has been detected and, if not, control proceeds to 914 where the system queries as to

whether the railcar 103 is stationary. If the railcar 103 is moving, control returns to 908, the system waiting state, having the derailment event enabled. If at 910 a derailment is detected, control proceeds to 912 where a system report of a derailment is made and control then proceeds to 914 as before. If, at 914, it is determined that the railcar 103 is again stationary, the derailment event is disabled at 916 and control returns to 902, where the system waits in a state where the derailment event is disabled.

[0060] Vertical Impact – A vertical impact message is regarded as a medium priority type of event. When a vertical impact event is received from a WSN 104, CMU 101 starts a vertical impact processing timer during which CMU 101 waits to see if any other vertical impact events are received from other WSN 104s. Depending on which side of the railcar 103 vertical impact messages are being generated, it can be determined, for example, that a broken rail or other track condition may exist.

[0061] Wheel Damage – A wheel damage message is regarded as a low priority type of event. When a wheel damage event is received from a WSN 104, CMU 101 starts to listen for additional wheel damage events from the same WSN 104. Thus, if CMU 101 receives multiple wheel damage messages from the same WSN 104, it can generate a wheel damage message. In such cases, CMU 101 may instruct WSN 104 to stop looking for wheel damage events as these will likely continue to recur and generate a barrage of messages from WSN 104 to CMU 101. In addition, the WSN 104 will have a counter to determine if it is sending wheel damage messages to the CMU 101 at a certain rate. If that rate is exceeded, the WSN 104 stops checking for wheel damage messages for a certain time period. After the time period has expired, the WSN 104 will check to see if the rate of wheel damage messages are still too high to send to the CMU 101.

[0062] Figure 10 is a flow chart showing the conditions under which the wheel damage and vertical impact events are enabled or disabled. At 1002, the system is initialized and, at 1004, the system is placed in a waiting state

wherein the events are disabled, as the critical speed required for event enablement has not yet been reached. Wheel damage and vertical impact events are only enabled when railcar 103 has reached a specific critical speed. Note that the speed of railcar 103 can be determined by several means, one preferred way is for a message to be sent from PWG 102 to all CMUs 101 in train consist 109. At 1006, the system checks to see if the critical speed has been reached or exceeded. The critical speed is a configurable setting of the system, typically set by each individual user, based on track and operational conditions, and is used to identify that the train is moving at a speed when such data is relevant. If not, control returns to 1004 where the system is again placed in a waiting state with the events disabled. If, at 1006, the critical speed has been reached or exceeded, control proceeds to 1008 where both the vertical impact and wheel damage events are enabled. Control then proceeds to 1010, where the system is placed in a waiting state having both types of events enabled. At 1012, if a vertical impact event has been detected, control proceeds to 1014 where the system reports the vertical impact. At 1016, the system checks to see if a wheel damage event has been detected and, if so, reports the wheel damage at 1018. In any event, control then proceeds to 1020, where the system checks to see if the railcar 103 is still at the critical speed necessary for the enablement of events. If it is, the system proceeds back to 1010 where the system is placed in a waiting state with events enabled. If the speed of railcar 103 has fallen below the critical speed, control proceeds to 1022 where both the vertical impact and wheel damage events are disabled, and then to 1004 where the system is placed in a waiting state with events disabled.

[0063] The proceeding acceleration events are all events which are detected by the variety of WSN 104 which is attached to the wheel roller bearing fitting 111 on railcar 103. The following events are all generated by the variety of WSN 104 which is attached to the body of railcar 103.

[0064] Longitudinal Impact – A longitudinal impact occurs when an acceleration is detected along the length of railcar 103, and is regarded as a medium priority type of event. When a longitudinal impact message is received from a WSN 104, the CMU 101 starts a timer during which it looks for other longitudinal impact events from other WSNs 104. Longitudinal impact events are likely to occur, for example, during the coupling process and when the train consist 109 starts and stops. CMU 101 may coordinate with other CMUs 101 on other railcars 103 to determine if longitudinal impact events which are generated on each railcar 103 originate from the same physical event.

[0065] Figure 7 is a flow chart showing the conditions under which longitudinal events are enabled. At 700, the system is initialized and at 702 the longitudinal events are enabled. The control then proceeds to 704 where the system is placed in a wait state with the events enabled and enters a detection loop. At 706 the system determines whether a longitudinal impact has been occurred and, if not, returns to 704 where the system again enters the wait state. At 706, if a longitudinal impact has been detected, control transfers to 708 where the system generates and reports a message regarding the impact. Control then returns to 704 where the system again enters the wait state.

[0066] Vertical Extreme Vehicle Dynamics – A vertical extreme vehicle dynamics event occurs when an acceleration is detected in the vertical direction of railcar 103, and is regarded as a medium priority type of event. An event is detected by a peak acceleration threshold being exceeded by an acceleration along the vertical axis. When a vertical extreme vehicle dynamics message is received from a WSN 104, the CMU 101 starts a timer during which it looks for other vertical extreme vehicle dynamics events from other WSNs 104. Vertical extreme vehicle dynamics events are likely to occur, for example, from a subsidence in the track or change in track modulus at a bridge abutment. CMU 101 may coordinate with other CMUs 101 on other railcars 103 to determine if vertical extreme vehicle dynamics events which are generated on each railcar 103 originate from the same physical event.

[0067] Lateral Extreme Vehicle Dynamics– A lateral extreme vehicle dynamics event occurs when an acceleration is detected in the lateral, or cross line, direction of railcar 103, and is regarded as a medium priority type of event. An event is detected by a peak acceleration threshold being exceeded by an acceleration along the lateral axis. When a lateral extreme vehicle dynamics message is received from a WSN 104, the CMU 101 starts a timer during which it looks for other lateral extreme vehicle dynamics events from other WSNs 104. Lateral extreme vehicle dynamics events are likely to occur, for example, from a subsidence in the track or change in track modulus at a bridge abutment. CMU 101 may coordinate with other CMUs 101 on other railcars 103 to determine if lateral extreme vehicle dynamics events which are generated on each railcar 103 originate from the same physical event.

[0068] Vertical Hunting – Vertical hunting is a condition that can last a long time with certain dynamic conditions such as track corrugation. The WSN 104s located on each end of the railcar 103 body are commanded to periodically check for vertical hunting simultaneously, which allows a phase comparison of the readings from each WSN 104. When CMU 101 receives a vertical hunting message, a vertical hunting processing timer is started and CMU 101 waits to see if another WSN 104 has reported a vertical hunting event during a predetermined time interval. If multiple events are received within the time interval, CMU 101 examines the messages received and if the data indicates similar periodic oscillations at each end of the railcar 103, then the phase relationship between events occurring at each end of the railcar 103 is determined. For an in phase oscillation, the CMU 101 generates a railcar "body bounce" event. When the data indicates out of phase oscillation, CMU 101 generates a railcar "body pitch" event. In both cases the vertical hunting message is reported by CMU 101.

[0069] Lateral Hunting – Lateral hunting is a condition that can last a long time with certain dynamic conditions. Factors that contribute to lateral hunting include: high center of gravity railcars 103, worn trucks (bogies), and worn tangent

track. The lateral hunting event detection works in a fashion similar to the detection of the vertical hunting events. When CMU 101 receives a lateral hunting event from one of the WSNs 104s on one end of the railcar 103 (e.g., the front end), a timer is started and, if another event is received from another WSN 104 on the other end of the same railcar (e.g., the back end) within a predetermined period of time then the events are compared for their phase relationship. If the data indicates an out of phase oscillation, then a "body yaw" event is generated. However, if the data indicates an in phase oscillation a "body roll" event is generated. In either case, a lateral hunting message is reported by CMU 101.

[0070] Figure 8 is a flow chart showing the enabling, disabling, and reporting of vertical and lateral hunting events. At 800, the system is initialized and, at 802, the system is placed in a waiting state with the events disabled. Events, in this case, are disabled when the speed of railcar 103 is below a critical speed. Vertical and lateral hunting events are only enabled when the speed of railcar 103 exceeds the critical speed. At 804, the system checks to see whether critical speed has been exceeded and, if not, returns to the system waiting state in 802. However, if the critical speed has been exceeded, at 806, the vertical and lateral hunting events are enabled and, at 808, the system enters a loop wherein the hunting data is sent to CMU 101 and then analyzed to see if a hunting event has occurred. At 810, CMU 101 analyzes the data and, at 812, determines whether or not a hunting event has been detected. If a hunting event has been detected, control proceeds to 814 where the event is reported. If no hunting event has been detected in 812, control proceeds directly to 816 where the system again checks to see if the speed of railcar 103 is over the critical speed. If the speed of railcar 103 is still high enough for hunting events to be enabled, control returns to 808 and the system again enters the loop. If the speed of railcar 103 has fallen below the critical speed, control proceeds to 818, where the hunting events are disabled, and then to 802, where the system is placed in the waiting state with events disabled.

[0071] With reference to Figs. 4 and 12, a general implementation model of the analysis system of a WSN 104 is now described. As depicted in the preferred embodiment, the analyzed signal (what is not filtered out by the mechanical filter 410 or potting material), originates with accelerometer hardware 404 and is passed to one or more sensor sections 1202, 1208 or 1214. These sensor sections select the data to be analyzed using a digital data filter 1204, 1210 or 1216, and passes this data on to a feature detector 1206, 1212 or 1218. Data selection can be based on, for example, direction (e.g. vertical or longitudinal components), frequency (e.g. high-frequency clangs or low frequency rocking), overall magnitude (combination of 2 or 3 directional components), or other variations of the collected data.

[0072] The feature detectors may use a variety of techniques to determine if specific features are present. Features may include but are not limited to, pulse peaks or duration, root mean square (RMS) level of magnitude values, or presence or lack of specific frequency components. Once a feature is detected, a message is passed on to message module 1220 to be delivered to the CMU 101. The sensor section may also perform periodic tests to determine if the feature is still present. If it is, the section can also determine if continued messages should be sent or if a message should be sent only when the feature is no longer present.

[0073] One possible implementation of the analysis system of Fig. 12 is shown in Figure 13. Here, accelerometer 404 passes data on to three sensor sections. The first section 1302 selects data from the longitudinal direction down the length of the railcar 103 and uses Longitudinal Section 1304 to extract longitudinal impact data. Longitudinal impacts are detected in Impact Detector 1306 when the peak value of the longitudinal data exceeds a longitudinal impact threshold. The second section 1308 selects data from the lateral direction across the railcar 103 and uses Lateral Section 1310 to extract lateral oscillation data. Lateral oscillations are detected in Vehicle Dynamics Detector 1312 when the RMS value of the oscillations exceeds a lateral oscillation threshold. The third section 1314 selects data from the vertical direction and uses Vertical Section 1316 to extract vertical oscillation data. Vertical oscillations are detected in Vehicle Dynamics Detector 1318 when the RMS value of

the oscillations exceeds a vertical oscillation threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

[0074] Another possible implementation of the analysis system is shown in Figure 14. Here, accelerometer 404 passes data on to three sensor sections. The first section 1402 looks at data from the vertical direction and uses Vertical Derailment Filter 1404 to extract the characteristic frequencies of a derailment. Derailment events are detected in Derailment RMS Detector 1406 when the RMS value of the filtered data exceeds a derailment threshold. The second section 1408 also selects data from the vertical direction, but uses Vertical Wheel Damage Filter 1410 to extract the characteristic frequencies of wheel damage. Wheel damage is detected in Wheel Damage RMS Detector 1412 when the RMS value of the filtered data exceeds a wheel damage threshold. The third section 1414 also selects data from the vertical direction and uses Vertical Impact Filter 1416 to extract vertical impact data. Vertical impacts are detected in Vertical Impact Peak Detector 1418 when the peak value of the filtered data exceeds a vertical impact threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

[0075] When a derailment occurs, the wheels of one or more axles fall off the rails and run along the track bed. The rough nature of the track bed causes the derailed wheels to experience high-energy vertical accelerations for the duration of the derailment. In a preferred embodiment, a derailment is readily identified by calculating the RMS value of a series of consecutive vertical acceleration measurements and comparing the result with a threshold. If the CMU sees such data from the WSNs on both sides of the same axle, this could indicate a derailment. On the other hand, acceleration data from a single WSN regarding just one wheel processed through sensor section 1408 is more likely to indicate a damaged wheel.

[0076] CMU 101 also collects temperature data from each WSN 104. The collection of temperature data from each WSN 104 must be synchronized to avoid conflicts between WSNs 104 while transmitting the data to CMU 101,

and to allow timely comparison and coordination of the temperature data from the readings from WSNs 104. This is achieved by storing the temperature data in a rotating buffer organized as one data set comprising one reading from each WSN 104 temperature sensor 406. In the preferred embodiment, each WSN 104 samples its temperature sensors 406 once per minute, four consecutive samples are averaged once every 4 minutes. The WSN 104 then sends a message containing 8 consecutive sample averages to the CMU 101 once every 32 minutes. CMU 101 keeps twenty samples in its rotating buffer for each temperature sensor 406, however, one of skill in the art would realize that other sampling intervals and buffer sizes could be used. It should be noted that WSNs 104 may have more than one temperature sensor 406. After each temperature message is received, the oldest set of data in the rotating buffer is discarded. When the data set is complete, the temperature data is examined for any significant temperature trends or events and then cleared so that the temperature data is used only once. As newer temperature messages are received, the buffer wraps around so that new data overwrites the oldest time slots. It should be noted that the WSNs 104 do not analyze the temperature data for specific events, but instead merely report it to the CMU 101. The CMU 101 examines the temperature data for trends and reports when certain thresholds have been detected. It should be noted that the temperature analysis is only performed when the train consist 109 is moving and is disabled when the train consist 109 is stationary. Therefore, WSNs 104 will not collect or report temperature data unless the train consist 109 is moving.

[0077] The following table is a listing of the alarms and warnings generated by the statistical analysis performed by the CMU 101 on the temperature data.

Peak Analysis	Greater than x% of the temperature readings in the analysis statistics exceed the absolute temperature analysis threshold

Ambient Analysis	Greater than y% of temperature readings in the analysis statistics exceed the above ambient temperature analysis threshold
Rate Analysis	z% of the operational time exhibits a temperature rise exceeding the temperature rate analysis threshold

The variables x, y and z, in the above table indicate that these numbers are configurable depending on the preferences of the user or customer. As an example of a Peak Analysis operation, if x (as configured by the user, e.g., 20, 25 or 30) percentage of temperature readings on a bearing over a period of time exceed the absolute temperature analysis threshold, an alarm or warning may be sent. As an example of the usefulness of carrying out the different analyses, it is possible that the Ambient Analysis on a hot bearing, if the train is running in very hot weather conditions, might not indicate a problem when in fact there might be one, while the Peak Analysis which looks just at the bearing temperature will provide a warning or alarm. On the other hand, in very cold weather, the Peak Analysis may not indicate a problem with a hot bearing due to the cold weather cooling down the bearing, while the Ambient Analysis would. An example of Rate Analysis – when the railcar is not moving, a bad bearing will be at ambient temperature, but once the railcar starts moving, the bad bearing may heat up quicker than the other bearings on the railcar, and therefore will have a higher percentage of operational time it exceeds the threshold temperature rate.

[0078] As with acceleration events, WSNs 104 are also able to check for temperature events and report when the measured temperature exceeds certain thresholds. The table below lists these temperature-related alarms and events that can be provided immediately:

Peak Alarm	Absolute temperature alarm threshold is exceeded
Peak Warning	Absolute temperature warning threshold is exceeded
Ambient Alarm	Temperature above ambient alarm threshold is exceeded
Ambient Warning	Temperature above ambient warning threshold is exceeded
Differential Alarm	Temperature difference alarm threshold is exceeded between bearings on the same axle

The first four Alarms and Warnings in the above table are based on data preferably collected by individual WSNs and do not require any analysis other than the exceeding of a threshold and thus can be initiated by the WSN that collected the data. The last one, the Differential Alarm, requires data from at least two WSNs located on bearing fittings on opposite sides of an axle, and therefore the analysis and Alarm will preferably be carried out by the CMU.

[0079] Figure 11 is a flow chart showing the processing of events related to the measurement of temperatures of the wheel bearings of railcar 103. At 1100, the system is initialized and, at 1102, the system enters a waiting state wherein the temperature monitoring events are disabled. Events are disabled, in this case, when the railcar 103 is not moving. At 1104, the system checks to see if the railcar is moving and, if not, returns to 1002 where it again enters the waiting state with events disabled. If the railcar is moving, control proceeds to 1106 where the temperature monitoring events are enabled. The system then proceeds to 1108 where it enters a loop wherein events are checked. Control proceeds to 1110 where the system again checks to see

make sure the railcar 103 is moving. If the railcar 103 is not moving, control proceeds to 1112 where the temperature monitoring events are disabled and then back to 1102 where the system is placed in a waiting state with events disabled. If, at 1110, the railcar 103 is still moving, control proceeds to 1114 where the system checks to see if a set of temperature measurements are available. If not, control returns to 1108 where the system is in the waiting state with events enabled. If a set of temperature measurements is available in 1114, control proceeds to 1116 wherein the WSN 104 transmits the set of temperature measurements to CMU 101. At 1118, CMU 101 performs an analysis of the temperature measurements, including all those in the rotating buffer and, in at 1120, decides if a temperature threshold has been exceeded. If not, control returns to 1108 where the system is in a waiting state with events enabled. If a temperature threshold has been exceeded, the system reports the temperature measurements at 1122 and then returns to 1108 where it is again in the system waiting state with events enabled.

[0080] CMU 101 also detects long term trends and keeps data regarding trends in the analysis of bearing condition. The following statistics are collected for every bearing being monitored by a WSN 104 in the railcar-based mesh network 105:

1. Total number of valid temperature readings;
2. Sum of valid temperature readings;
3. Sum of valid temperature readings squared;
4. Number of temperature readings greater than the absolute temperature threshold;
5. Number of temperature readings greater than the above ambient temperature threshold; and
6. Number of temperature change rates greater than the heating rate threshold.

[0081] The bearing temperature statistics are accumulated on a daily basis in a rotating buffer that can hold thirty-two sets of data, thus allowing trend analysis over a thirty-day period. The DCEP engine controls the time that statistics are accumulated as a new set of statistics has begun and the oldest is discarded. Normally the event engine is configured to generate an analysis once per day.

[0082] The collected statistics may be used to calculate information that indicates bearing wear trends. In a preferred embodiment, a CMU 101 provides a report upon request of the following quantities for every wheel bearing:

a. Average bearing temperature;

b. Variance of bearing temperature;

c. Percentage of bearing temperature readings that exceed an absolute threshold;

d. Percentage of bearing temperature readings above ambient that exceed a threshold; and

e. Percentage of measurements that the rate of increase of bearing temperature exceeds a threshold.

[0083] A **train-based mesh network** is shown generally as reference number 107 in Figs. 2 and 3. Train-based mesh network 107 is overlaid on a train consist 109 and includes a PWG 102 installed on a host or control point such as a locomotive 108, or on another asset with access to a power source, and one or more CMUs 101, each belonging to the train-based mesh network 107 and also to their respective railcar-based mesh networks 105, if one or more WSNs 104 are present, or respective railcar-based mesh networks or network 118 for railcars 103 with a CMU 101 but no WSNs 104 (see Fig. 2). (Note that there can also be railcars 103 in train consist 109 without a CMU 101 thereon, as shown by reference number 119 in Figure 2). Thus, here, CMUs 101 can belong to two mesh networks, railcar-based mesh network 105 (if railcar 103 is fitted with one or more WSNs 104) and train-based mesh

network 107. Each CMU 101 is also optionally managing its respective railcar-based mesh network 105. Fig. 3 shows a case wherein the train-based mesh network 107 consists of three CMUs 101, two of which are part of railcar-based mesh networks 105, and one located on a railcar 103 (reference number 118) wherein no WSNs 104 are connected.

[0084] Train-based mesh network 107 uses an overlay mesh network to support low-power bi-directional communication throughout train consist 109 and with PWG 102 installed on locomotive 108. The overlaid train-based mesh network 107 is composed of wireless transceivers embedded in the CMU 101 on each railcar 103. Each CMU 101 is capable of initiating a message on the train-based mesh network 107 or relaying a message from or to another CMU 101. The overlay train-based mesh network 107 is created independently of, and operates independently of the railcar-based mesh networks 105 created by each railcar 103 in the train consist 109.

[0085] A bi-directional PWG 102 manages the train-based mesh network 107 and communicates alerts from the CMUs 101 installed on individual railcars 103 to the host or control point, such as the locomotive 108, wherein the alerts or event reports may be acted upon via human intervention, or by an automated system. Locomotive 108 may include a user interface for receiving and displaying alert messages generated by train-based mesh network 107 or any of the individual railcar-based mesh networks 105. Bi-directional PWG 102 is capable of receiving multiple alerts or events from CMUs 101 on individual railcars 103 and can draw inferences about specific aspects of the performance of train consist 109.

[0086] Bi-directional PWG 102 is also capable of exchanging information with an external remote railroad operations center 120, data system or other train management system. This communication path is shown in Fig. 3 as reference number 122, and can include cellular, LAN, Wi-Fi, Bluetooth, satellite, or other means of communications. This link can be used to send alerts off-train consist 109 when the train consist 109 is in operation.

[0087] It is appreciated that described above are novel systems, devices and methods. It is also understood that the invention is not limited to the embodiments and illustrations described above, and includes the full scope provided by the claims appended hereto.

* * * * *

We claim:

1. A system for detecting operational anomalies on a train consist or railcar comprising:

a) one or more communication management units mounted on one or more railcars;

b) one or more sensors located on said one or more railcars for sensing an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units; and

c) wherein said communication management units perform the functions of:

i) collecting data regarding said one or more railcar operational parameters;

ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

iii) communicating a message to a remote receiver when said trend or event is detected.

2. The system of claim 1 further comprising one or more wireless sensor nodes in communication with one of said communication management units, said one or more sensors forming part of said one or more wireless sensor nodes.

3. The system of claim 2 wherein each of said wireless sensor nodes performs the functions of:

a) collecting data from one or more sensors;

b) comparing said data against one or more rules; and

c) sending a message to said communication management unit when at least one of said rules is satisfied.

4. The system of claim 2 wherein each of said wireless sensor nodes performs the functions of:

a) collecting data from one or more sensors; and

b) periodically sending said collected data to said communication management unit.

5. The system of claim 3 wherein said one or more rules are numerical thresholds which, when exceeded by said collected data, cause an alert message to be sent to said communication management unit.

6. The system of claim 5 wherein said data is acceleration data.

7. The system of claim 5 wherein said data is temperature data.

8. The system of claim 5 wherein said communication management unit, upon receiving an alert message from one of said wireless sensor nodes, performs the functions of:

a) waiting to see if similar messages are received from one or more other wireless sensor nodes within a predetermined period of time and concluding that an actual event has occurred if said similar messages are received; and

b) communicating a message reporting the occurrence of said actual event to a remote receiver.

9. The system of claim 4 wherein said communication management unit, upon receiving said periodically sent data, performs the functions of:

a) storing said data in a data store;

b) analyzing said stored data for trends; and

c) generating a report when trends of interest are detected.

10. The system of claim 8 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to see if acceleration thresholds representing one or more of the following have been exceeded: wheel damage, vertical impacts or derailment.

11. The system of claim 8 wherein said wireless sensor node is mounted on the body of a railcar and further wherein said data is analyzed to see if acceleration thresholds representing one or more of the following have been exceeded: vertical hunting,

lateral hunting, vertical extreme vehicle dynamics, lateral extreme vehicle dynamics, or longitudinal impacts.

12. The system of claim 7 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to see if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded.

13. The system of claim 8 wherein said communication management unit confirms that a derailment event has occurred when derail messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

14. The system of claim 8 wherein said communication management unit confirms that vertical hunting is occurring when vertical hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

15. The system of claim 14 wherein said communication management unit determines that a body bounce event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate in phase accelerations were detected.

16. The system of claim 14 wherein said communication management unit determines that a body pitch event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate out of phase accelerations were detected.

17. The system of claim 8 wherein said communication management unit confirms that a lateral extreme vehicle dynamic event has occurred when lateral extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

18. The system of claim 8 wherein said communication management unit confirms that a vertical extreme vehicle dynamic event has occurred when vertical extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

19. The system of claim 8 wherein said communication management unit confirms that lateral hunting is occurring when lateral hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

20. The system of claim 19 wherein said communication management unit determines that a body yaw event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate out of phase accelerations were detected.

21. The system of claim 19 wherein said communication management unit determines that a body roll event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate in phase accelerations were detected.

22. The system of claim 7 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to determine if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded.

23. The system of claim 4 wherein said data is temperature data.

24. The system of claim 3 wherein said wireless sensor nodes are mounted on wheel bearing fittings of a railcar on opposite sides of a same axle, and wherein said communication management unit generates a differential temperature alert when

temperatures reported by said wireless sensor nodes on said opposite sides of said axle exceed a differential threshold.

25. The system of claim 23 wherein said communication management unit generates an alert if greater than a certain percentage of the temperature readings received exceed an absolute temperature threshold or an above ambient temperature threshold.

26. The system of claim 23 wherein said communication management unit generates an alert if greater than a certain percentage of temperature readings indicate a temperature rise rate exceeding a certain threshold.

27. The system of claim 3 wherein said communication management unit can instruct each wireless sensor node to enable or disable the checking of individual rules by sending a message to said wireless sensor node.

28. The system of claim 4 wherein said communication management unit can instruct each wireless sensor node to enable or disable the periodic sending of data by sending a message to said wireless sensor node.

29. The system of claim 3 wherein each communication management unit in communication with one or more wireless sensor nodes form a railcar-based mesh network comprising said communication management unit and said wireless sensor nodes, said railcar-based mesh network being controlled by said communication management unit.

30. The system of claim 29 wherein said communication management unit includes wireless sensor nodes from other railcars in its railcar-based mesh network.

31. The system of claim 1 further comprising a powered wireless gateway controlling a train-based network that includes said powered wireless gateway and a plurality of said communication management units.

32. The system of claim 31 wherein said powered wireless gateway serves as said remote receiver.

33. The system of claim 1 wherein said remote receiver is located off-train.

34. The system of claim 33 wherein said communication management unit communicates with said off-train remote receiver via a communication means comprising one of cellular, satellite, WiFi and Bluetooth.

35. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:

a) collecting data regarding said one or more railcar operational parameters;

b) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

c) communicating a message to a remote receiver when said trend or event is detected.

36. The method of claim 35 wherein steps (a) – (c) are performed by a communication management unit located on a railcar in said train consist.

37. The method of claim 36 wherein said data is collected from one or more wireless sensor nodes on said railcar, said wireless sensor nodes being in communication with said communication management unit.

38. The method of claim 37 wherein said communication management unit and said one or more wireless sensor nodes form a railcar-based mesh network.

39. The method of claim 37 wherein said wireless sensor nodes each perform the functions of:

a) collecting data from one or more sensors;

b) comparing said data against one or more rules; and

c) sending a message to said communication management unit when at least one of said rules is satisfied.

40. The method of claim 39 wherein said one or more rules causes data collected from some sensors to be periodically sent to said communication management unit.

41. The method of claim 39 wherein said data includes one or more of the following: acceleration data and temperature data.

42. The method of claim 37 wherein said communication management unit coordinates messages from two or more wireless sensor nodes to confirm that an event has occurred.

43. The method of claim 42 wherein acceleration events are selected from a group consisting of wheel damage, vertical impact, derailment, vertical hunting, lateral hunting and longitudinal impact.

44. The method of claim 42 wherein temperature events include one or more of the following absolute temperature alarm, above ambient temperature alarm, differential temperature alarm, peak analysis alarm, ambient analysis alarm and rate analysis alarm.

45. The method of claim 36 wherein all communication management units on said train consist are configured in a train-based wireless mesh network controlled by a powered wireless gateway.

46. The method of claim 35 wherein said remote receiver is off-train.

47. The method of claim 45 wherein said remote receiver is said powered wireless gateway.

48. The system of claim 1 wherein at least one of said communication management units includes at least one of said sensors.

49. The system of claim 3 wherein one of said wireless sensor nodes comprises:
a) a protective housing;
b) said one or more sensors mounted within said protective housing;
c) a communication capability, for communicating with said communication management unit; and
d) a microprocessor, executing firmware to control the operation of said wireless sensor node.

50. The system of claim 49 wherein said one or more sensors includes a sensor to measure accelerations and wherein said wireless sensor node is tuned to detect certain types of accelerations.

51. The system of claim 50 further comprising a mechanical filter which includes a resilient material selected to filter out undesirable accelerations, said mechanical filter disposed to remove said undesirable accelerations before said undesirable accelerations reach said accelerometer.

52. The system of claim 50 wherein said wireless sensor node further comprises potting material dispose within said housing, said potting material used to tune said wireless sensor node by absorbing undesirable accelerations.

53. The system of claim 49 wherein said firmware includes one or more software filters used to isolate certain types of accelerations.

54. The system of claim 49 wherein said firmware performs the functions of:
a) reading data from said one or more sensors;
b) comparing said data against a set of rules for reporting alerts or events; and

c) communicating an alert or event to said communication management unit when said data meets one or more of said rules.

55. The system of claim 49 wherein said firmware implements an analysis system for detecting events, said analysis system comprising:

a) one or more sensor sections, each of said sensor sections having:

i) a filter, for isolating particular accelerations of interest from data read from one or more acceleration detectors; and

ii) a feature detector, for detecting particular features of interest from said filtered data.

56. A system for detecting operational anomalies on a train consist or railcar comprising:

a) a train-based mesh network comprising a powered wireless gateway and one or more communication management units located on one or more railcars in said train consist;

b) one or more railcar-based mesh networks comprising said one or more communication management units, each arranged in a mesh network configuration with one or more wireless sensor nodes;

c) a distributed complex event processing engine distributed across said wireless sensor nodes, said communication management units and said powered wireless gateway, said distributed complex event processing engine detecting anomalous operating conditions on said train consist via data gathered by sensors controlled by said wireless sensor nodes and propagated upwards through said system.

57. A wireless sensor node configured for attachment to a railcar, comprising:

a. a protective housing;

b. a power source;

c. an accelerometer;

d. electrical circuitry for wireless communications and to control the operation of the wireless sensor node, and

e. said electrical circuitry includes a microprocessor capable of executing firmware with one or more software filters used to isolate certain types of accelerations.

58. The wireless sensor node of claim 57 further comprising a potting material within said housing in which said accelerometer is embedded, said potting material being selected to filter out undesirable accelerations from said railcar.

59. The wireless sensor node of claim 57 further comprising a mechanical filter made of a resilient material selected to filter out undesirable accelerations, and which is positioned to filter out the undesirable accelerations before said accelerations are detected by said accelerometer.

60. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

a. at least one communication management unit (CMU) mounted on the train consist;

b. at least two sensors located on the railcar for sensing operational parameters of the railcar, said sensors being in communication with said CMU;

c. wherein said CMU performs the following functions:

i) receiving data from said sensors;

ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and

iii) communicating a message to a remote receiver when an anomaly is detected.

61. The system of claim 60 wherein said sensors comprise accelerometers positioned at different locations of the railcar, and wherein said step of drawing inferences comprises the comparison of data from two or more of said accelerometers.

62. The system of claim 60 wherein said sensors comprise temperature sensors positioned at different locations of the railcar, and wherein said step of drawing inferences comprises the comparison of data from two or more said temperature sensors.

63. The system of claim 61 wherein said accelerometers are positioned on the railcar to provide data for carrying out one or more of the following functions:

i) compare accelerations from one railcar wheel with that of another railcar wheel on the same axle but opposite side of the railcar,

ii) compare accelerations from one railcar wheel with that of at least one other wheel on the same side of said railcar, and

iii) compare accelerations from one railcar wheel with that of at least one other railcar wheel on the same side of said one railcar wheel and which other wheel is on another railcar of the same train consist.

64. The system of claim 61 wherein said accelerometers are positioned on the railcar to provide data for carrying out one or more of the following functions:

i) compare accelerations from front and back ends of said railcar,

ii) compare accelerations from any two locations on the railcar, and

iii) compare accelerations from one railcar with those of another in the same train consist.

65. The system of claim 62 wherein said temperature sensors are positioned on the railcar to provide data for comparing temperature data from one railcar wheel bearing with that of another railcar wheel bearing on the same axle but on an opposite side of the railcar.

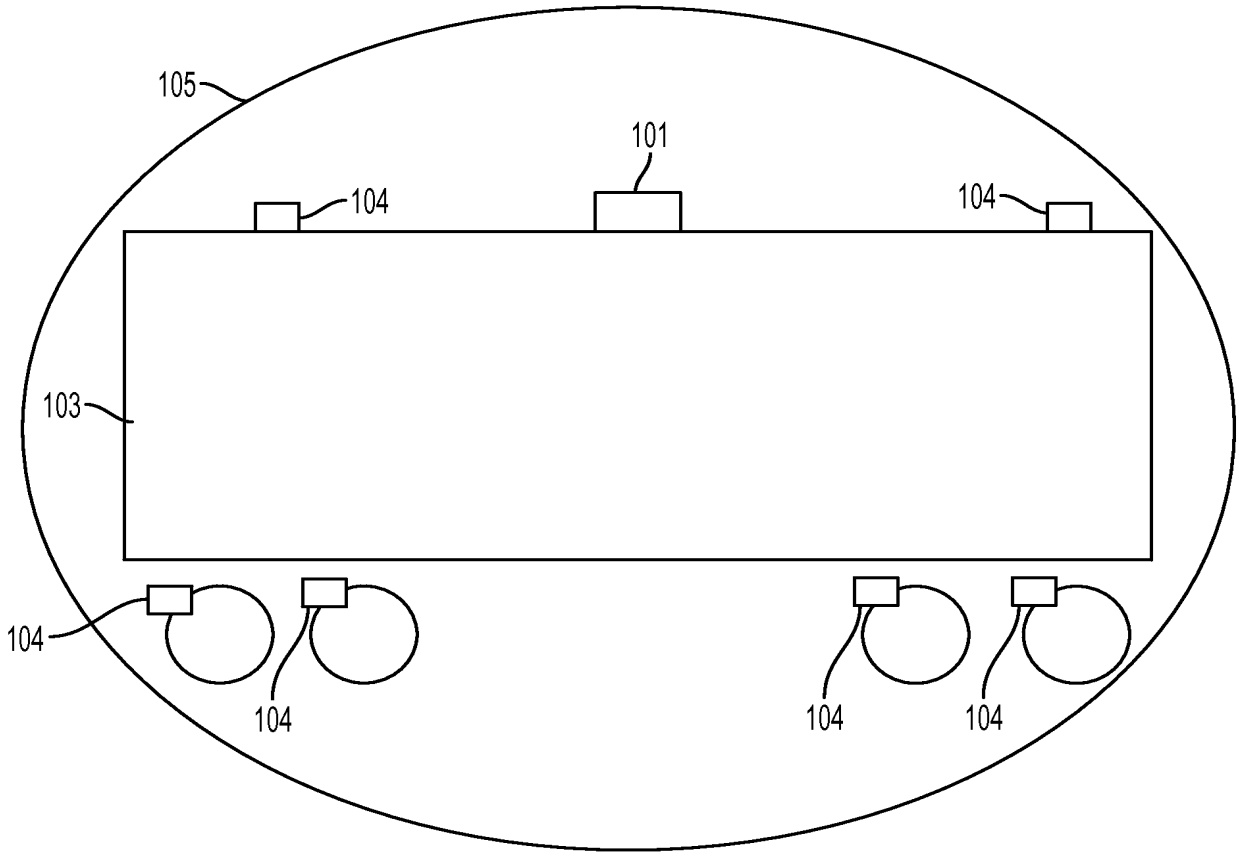


FIG. 1

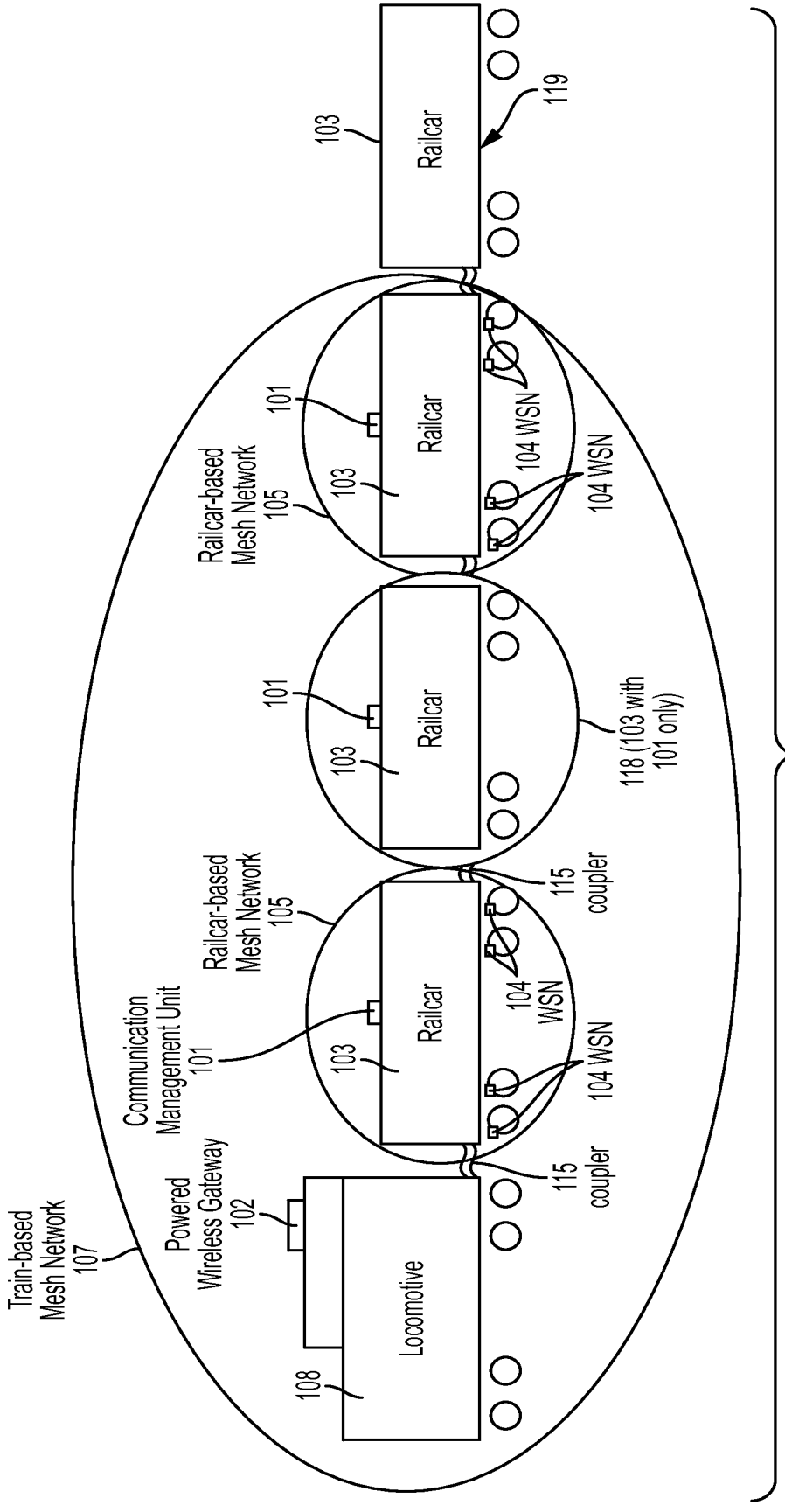

Train-based
Mesh Network
107
Powered
Wireless Gateway
102
Communication
Management Unit
101
Locomotive
108
Railcar-based
Mesh Network
105
Railcar
103
Railcar
101
104
WSN
104 WSN
115
coupler
Railcar
103
Railcar
101
118 (103 with
101 only)
Railcar-based
Mesh Network
105
Railcar
103
Railcar
101
104 WSN
104 WSN
Railcar
103
119
109
Train
Consist

FIG. 2

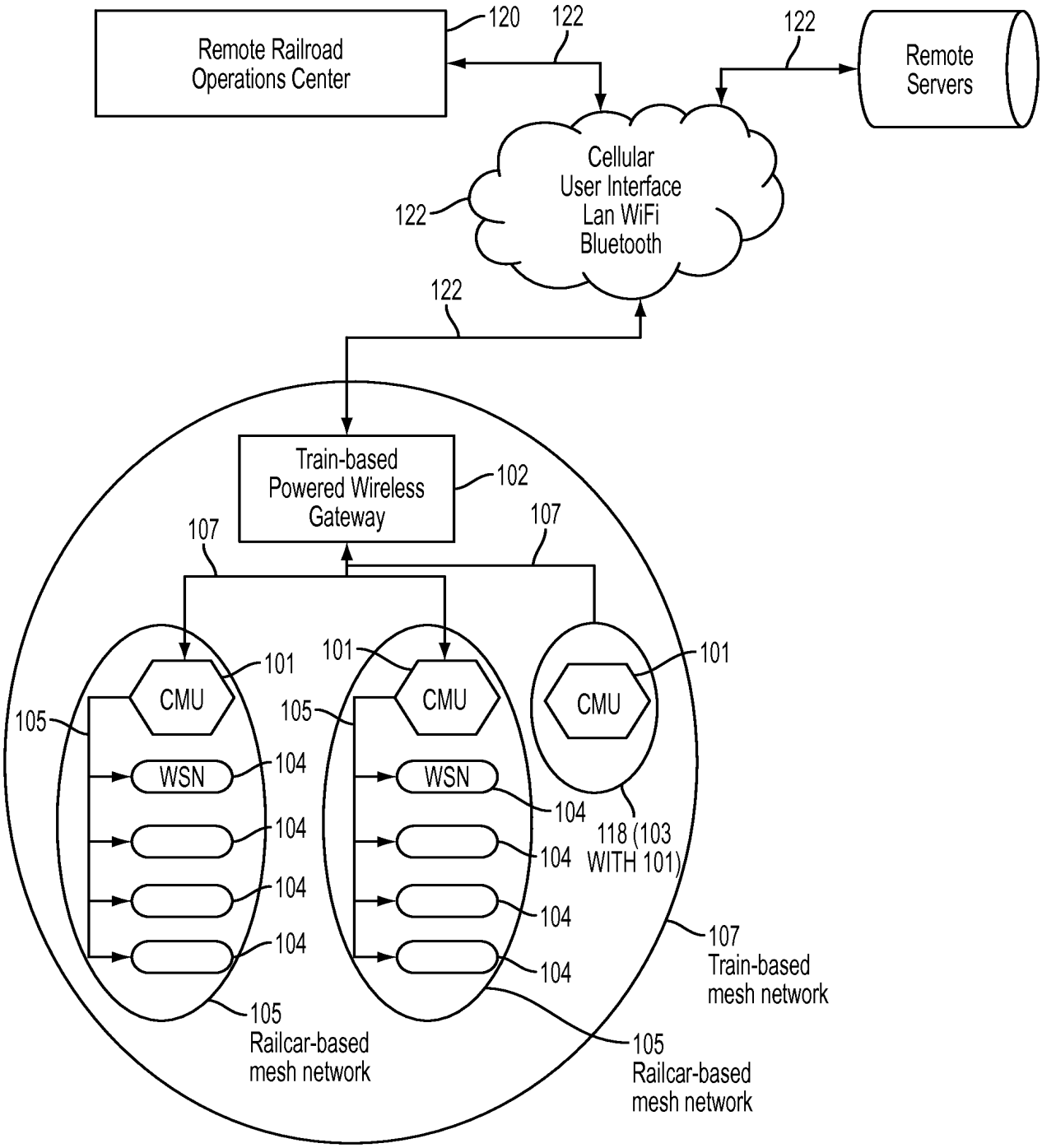

Remote Railroad Operations Center
120
122
122
Remote Servers
Cellular
User Interface
Lan WiFi
Bluetooth
122
122
Train-based Powered Wireless Gateway
102
107
107
CMU
101
105
WSN
104
104
104
104
105
Railcar-based mesh network
CMU
101
105
WSN
104
104
104
104
105
Railcar-based mesh network
CMU
101
118 (103 WITH 101)
107
Train-based mesh network

FIG. 3

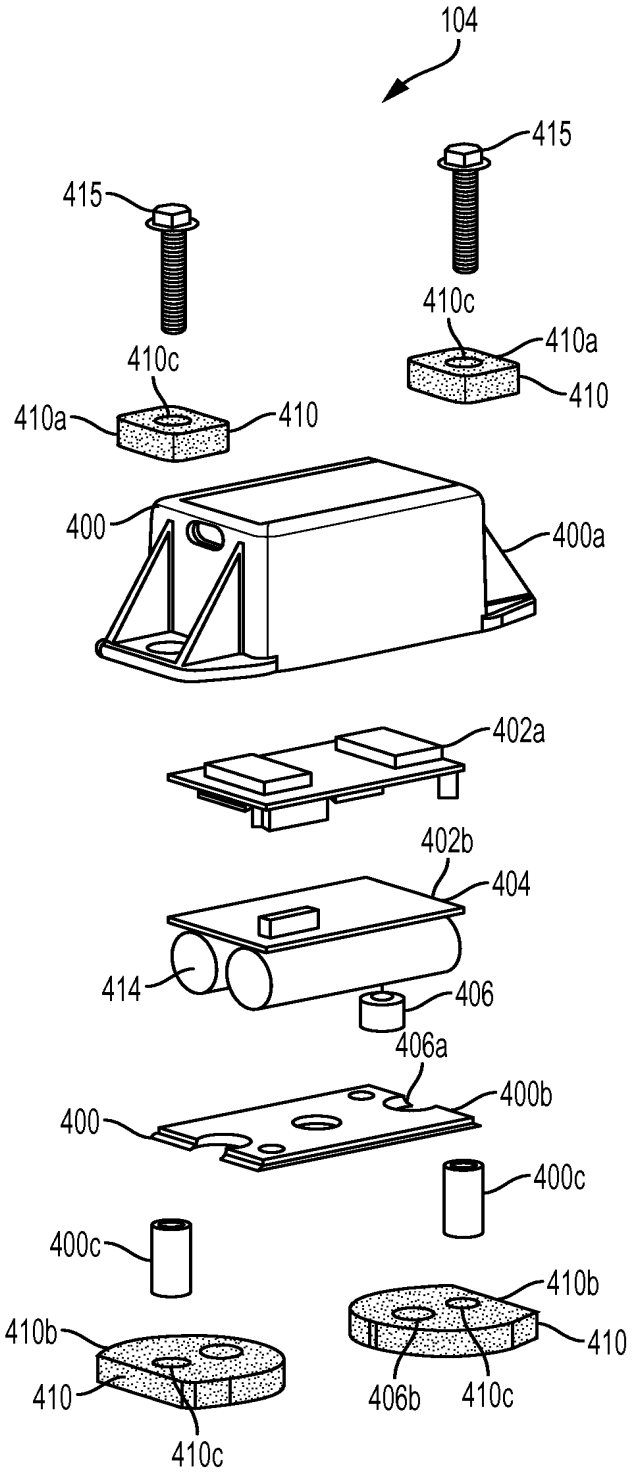

104
415
415
410c
410a
410
410c
410a
410
400
400a
402a
402b
404
414
406
406a
400
400b
400c
400c
410b
410
410b
410
406b
410c
410c

FIG. 4

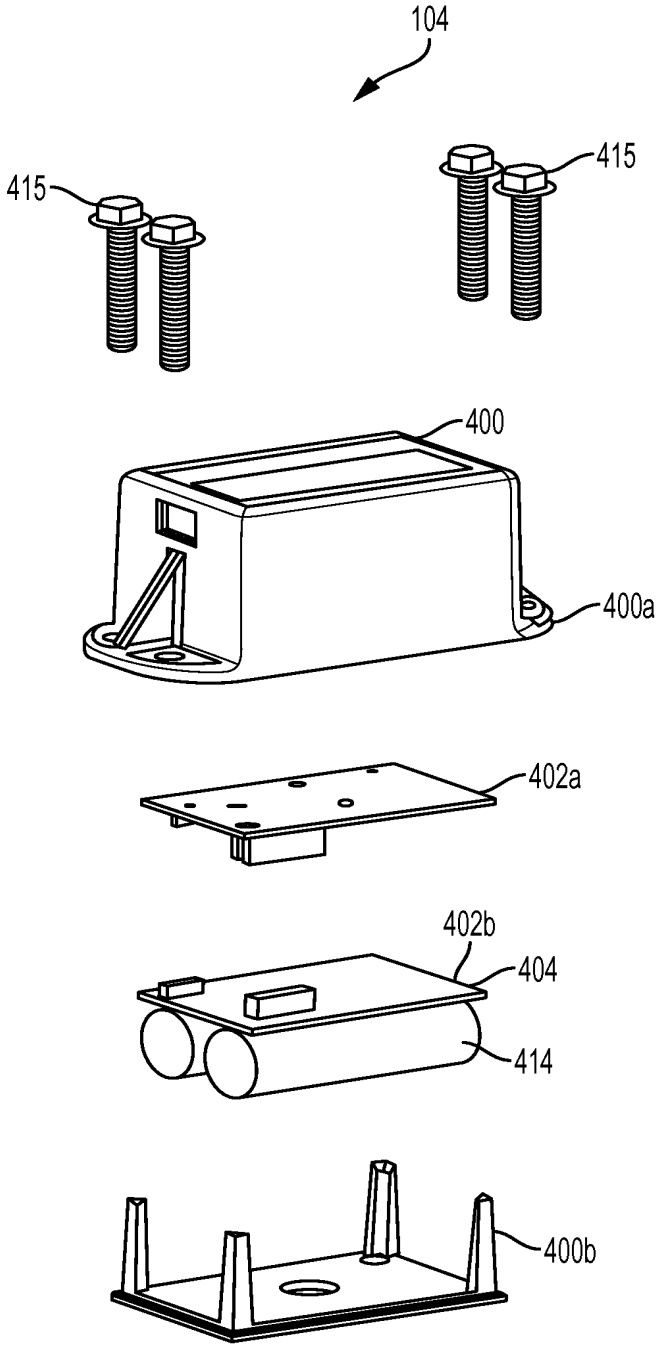


FIG. 5

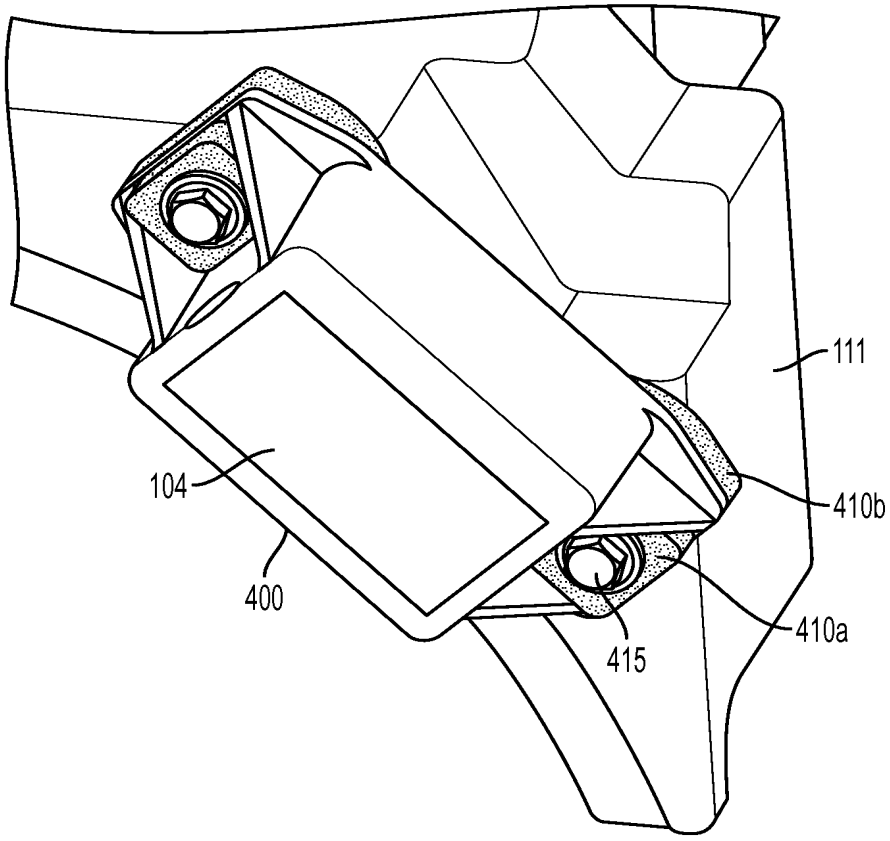


FIG. 6

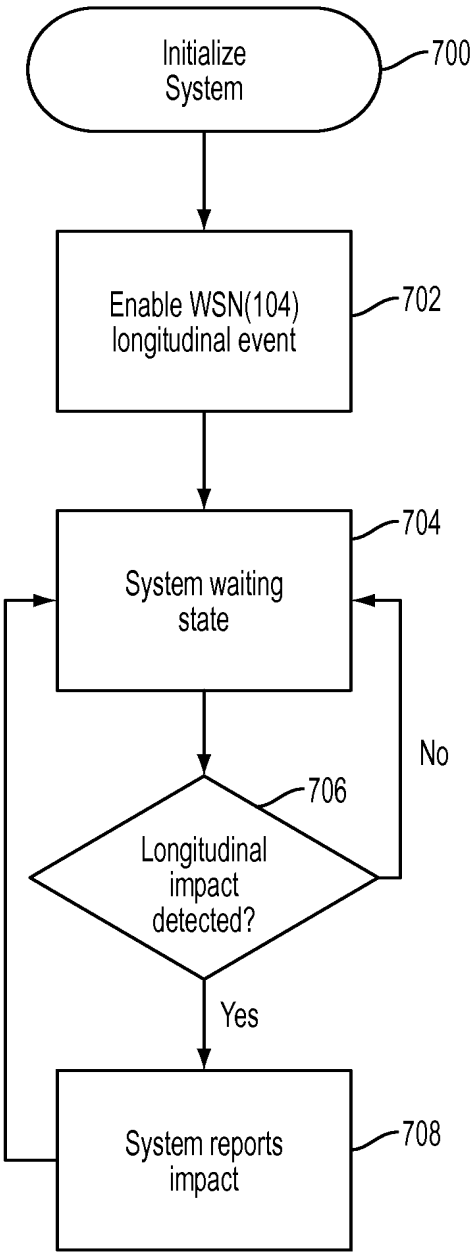

Initialize System
700
Enable WSN(104) longitudinal event
702
System waiting state
704
No
706
Longitudinal impact detected?
Yes
System reports impact
708

FIG. 7

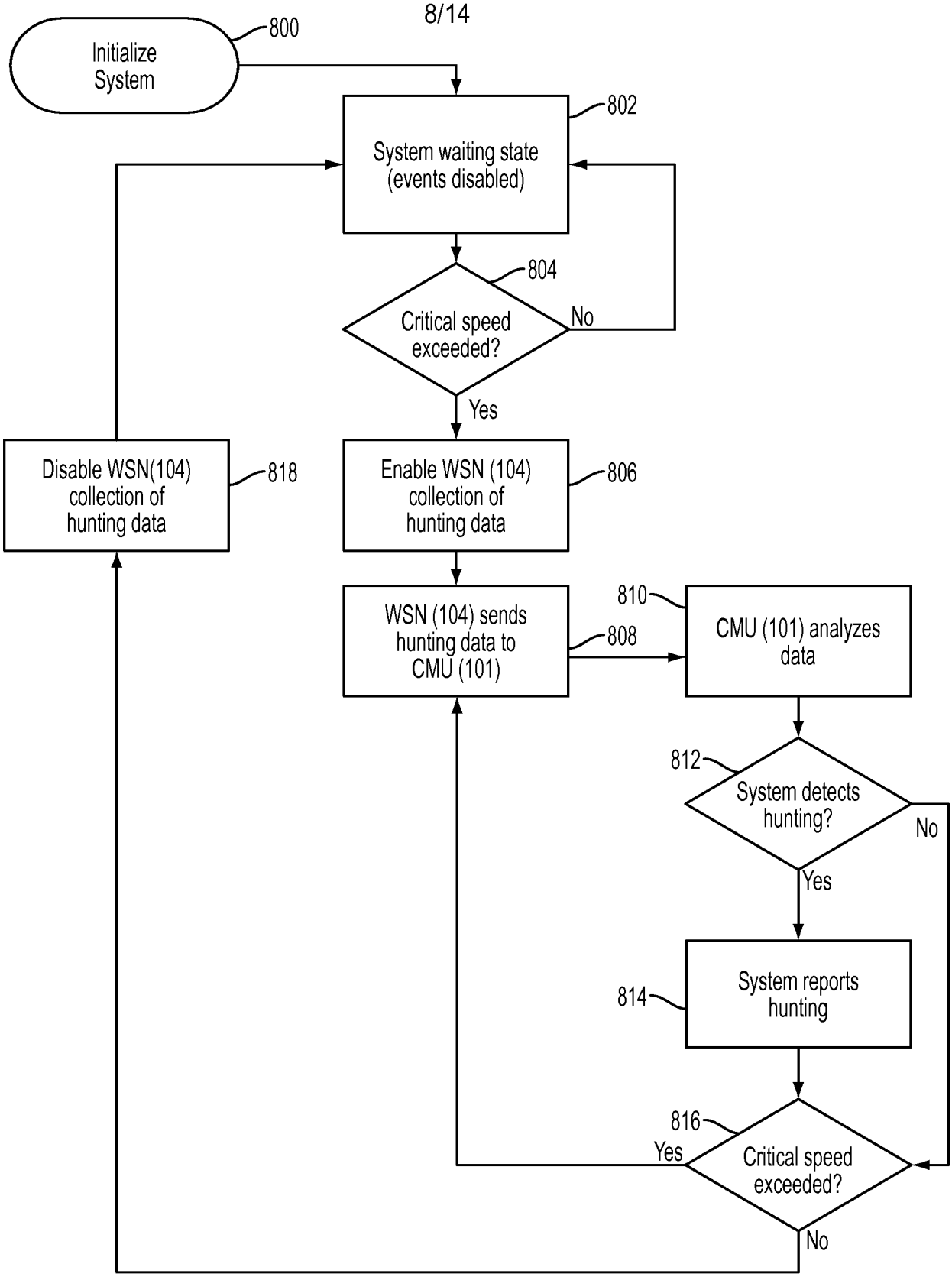

Initialize System
800
System waiting state (events disabled)
802
Critical speed exceeded?
804
No
Yes
Enable WSN (104) collection of hunting data
806
Disable WSN(104) collection of hunting data
818
WSN (104) sends hunting data to CMU (101)
808
CMU (101) analyzes data
810
System detects hunting?
812
No
Yes
System reports hunting
814
Critical speed exceeded?
816
Yes
No

FIG. 8

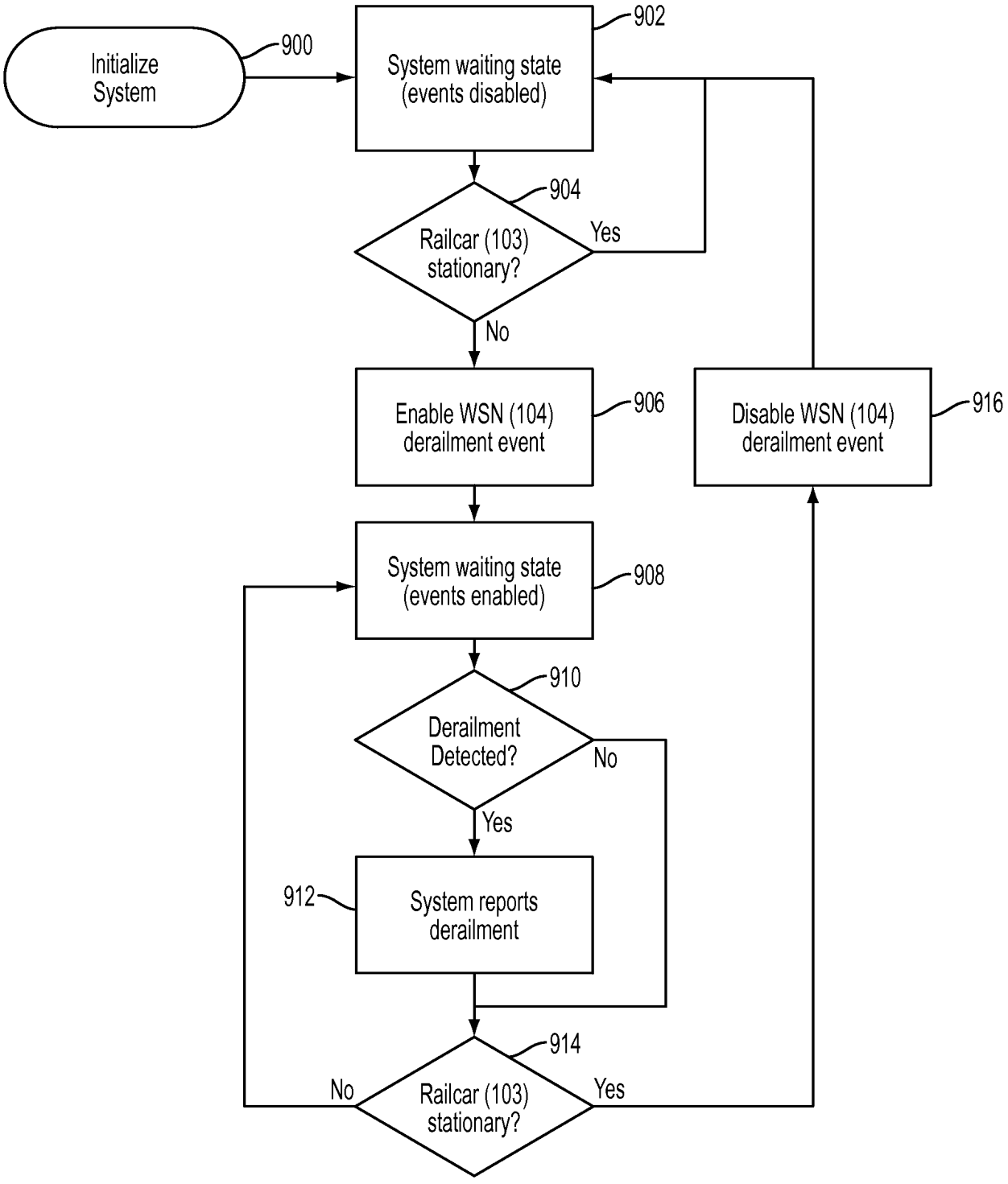

Initialize System
900
System waiting state (events disabled)
902
Railcar (103) stationary?
904
Yes
No
Enable WSN (104) derailment event
906
Disable WSN (104) derailment event
916
System waiting state (events enabled)
908
Derailment Detected?
910
No
Yes
System reports derailment
912
Railcar (103) stationary?
914
No
Yes

FIG. 9

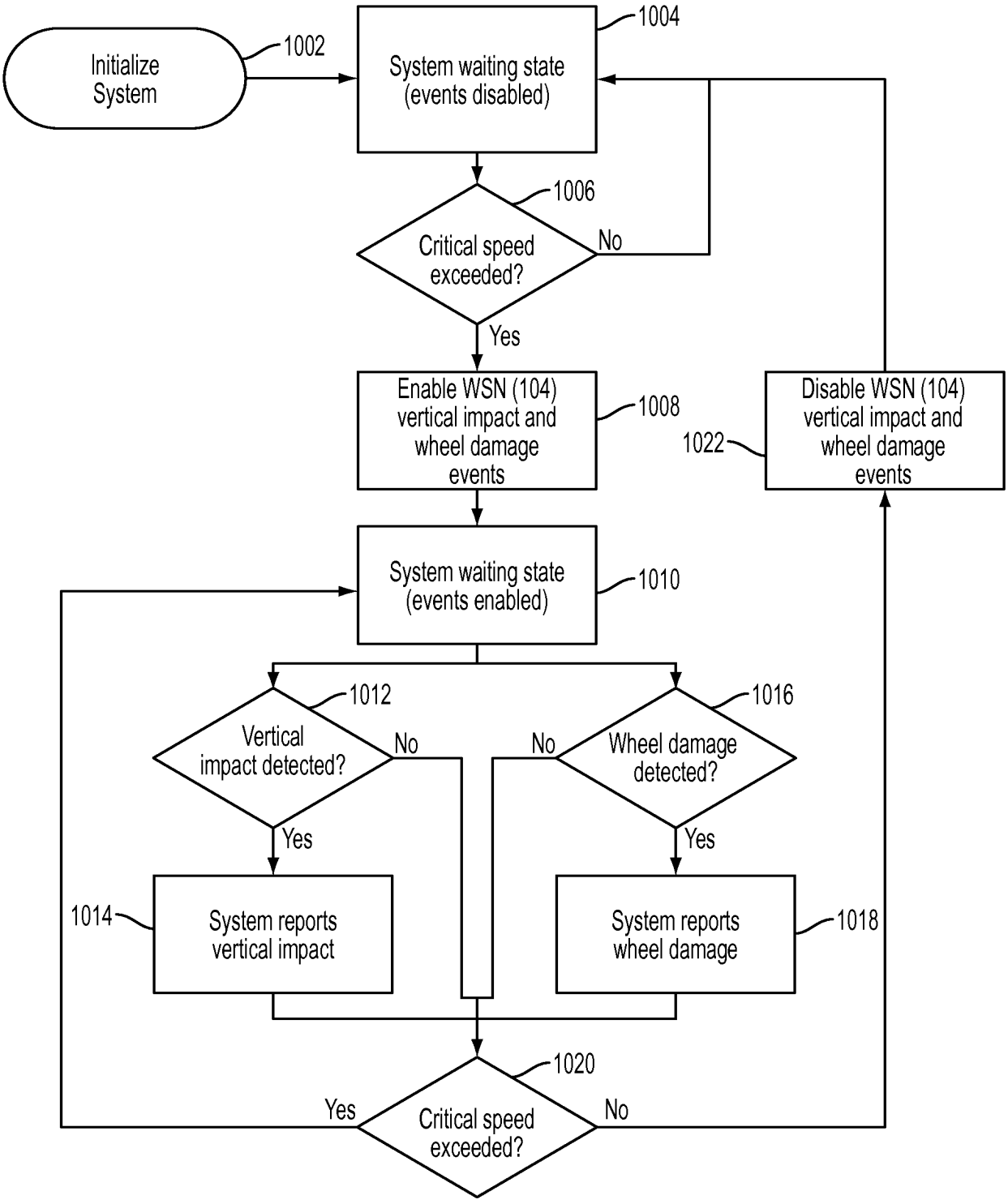

Initialize System
1002
System waiting state (events disabled)
1004
Critical speed exceeded?
1006
No
Yes
Enable WSN (104) vertical impact and wheel damage events
1008
Disable WSN (104) vertical impact and wheel damage events
1022
System waiting state (events enabled)
1010
Vertical impact detected?
1012
No
Yes
Wheel damage detected?
1016
No
Yes
System reports vertical impact
1014
System reports wheel damage
1018
Critical speed exceeded?
1020
Yes
No

FIG. 10

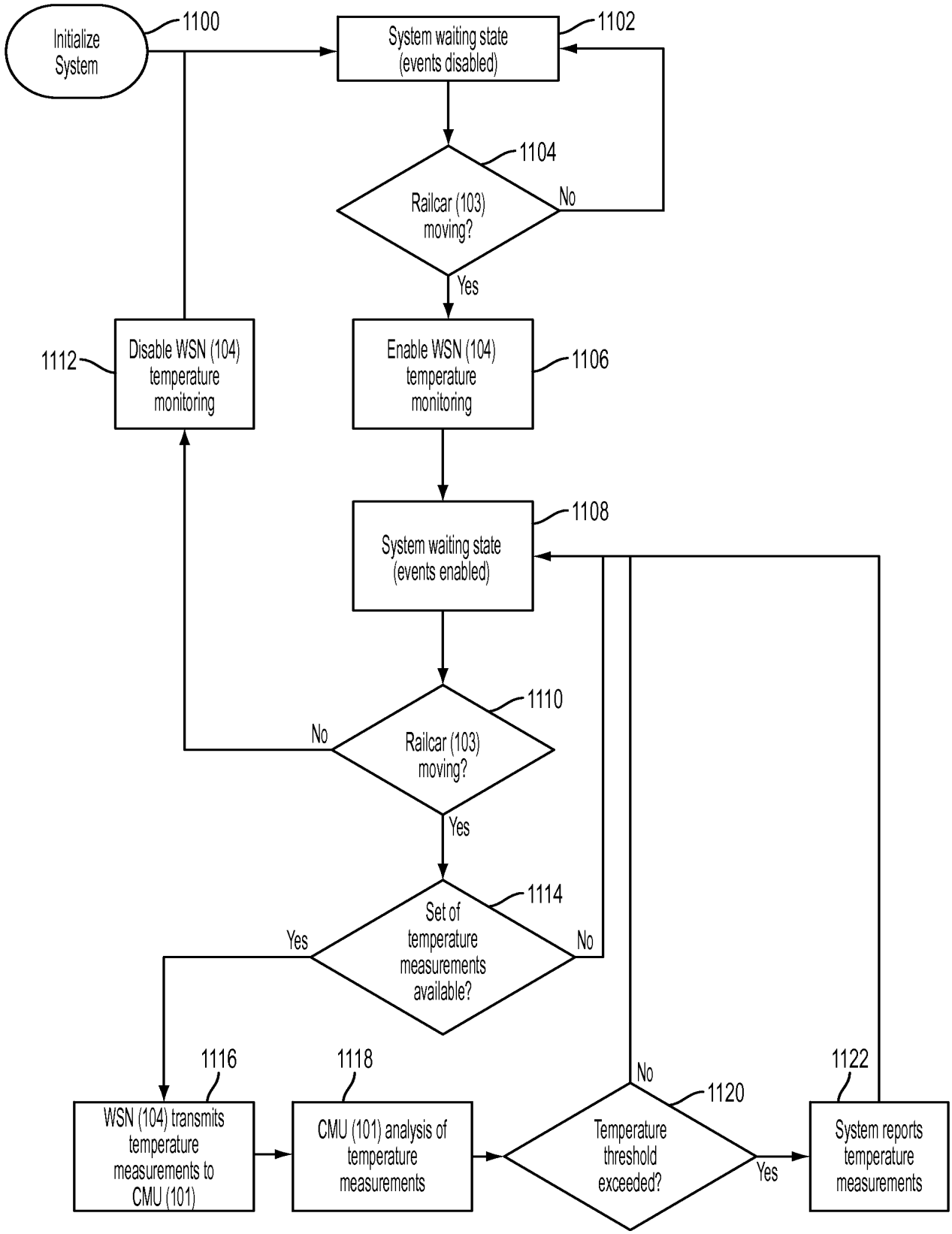

Initialize System
1100
System waiting state (events disabled)
1102
1104
Railcar (103) moving?
No
Yes
1112
Disable WSN (104) temperature monitoring
Enable WSN (104) temperature monitoring
1106
1108
System waiting state (events enabled)
1110
No
Railcar (103) moving?
Yes
1114
Set of temperature measurements available?
Yes
No
1116
WSN (104) transmits temperature measurements to CMU (101)
1118
CMU (101) analysis of temperature measurements
No
1120
Temperature threshold exceeded?
Yes
1122
System reports temperature measurements

FIG. 11

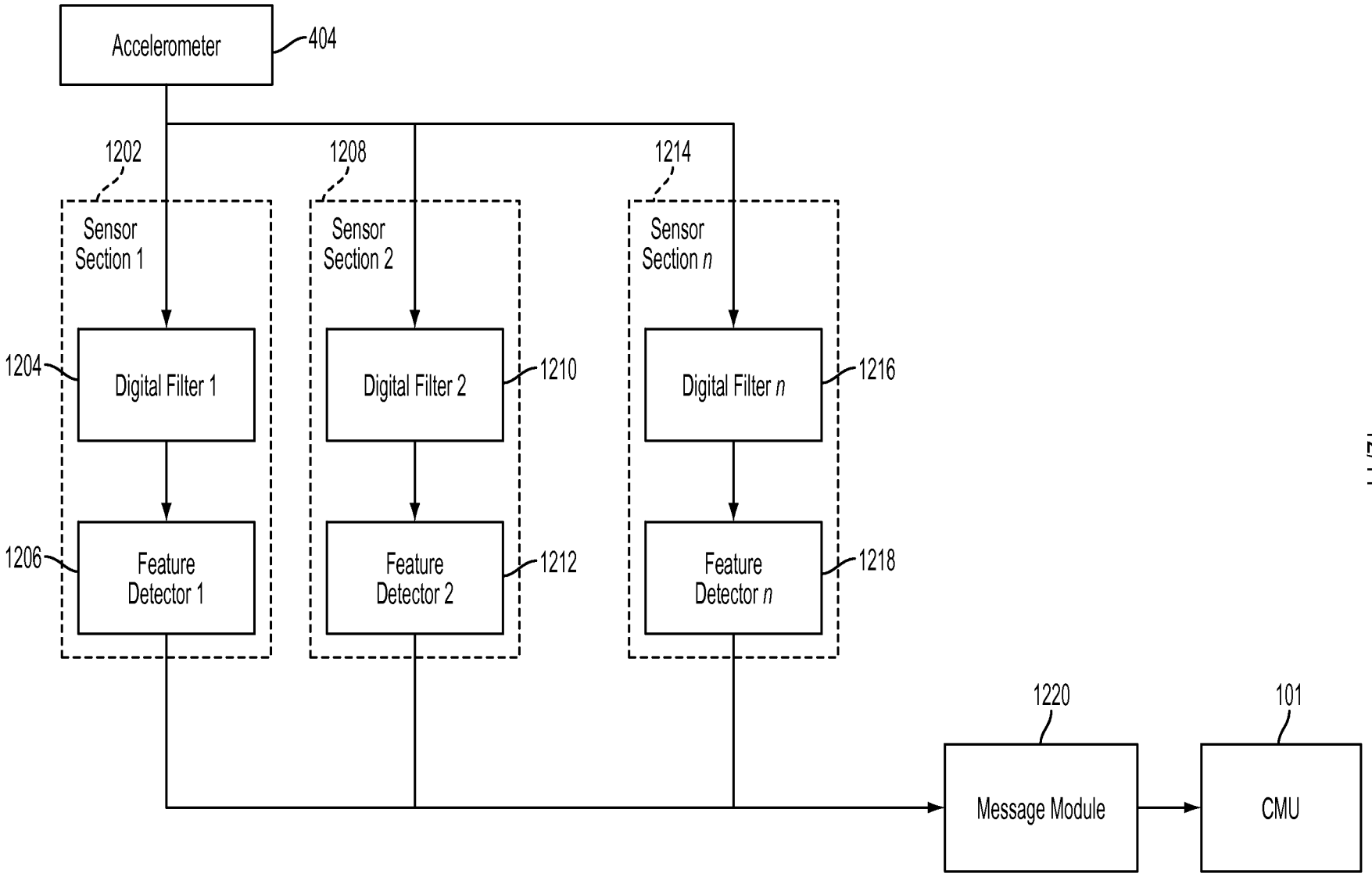


FIG. 12

SUBSTITUTE SHEET (RULE 26)

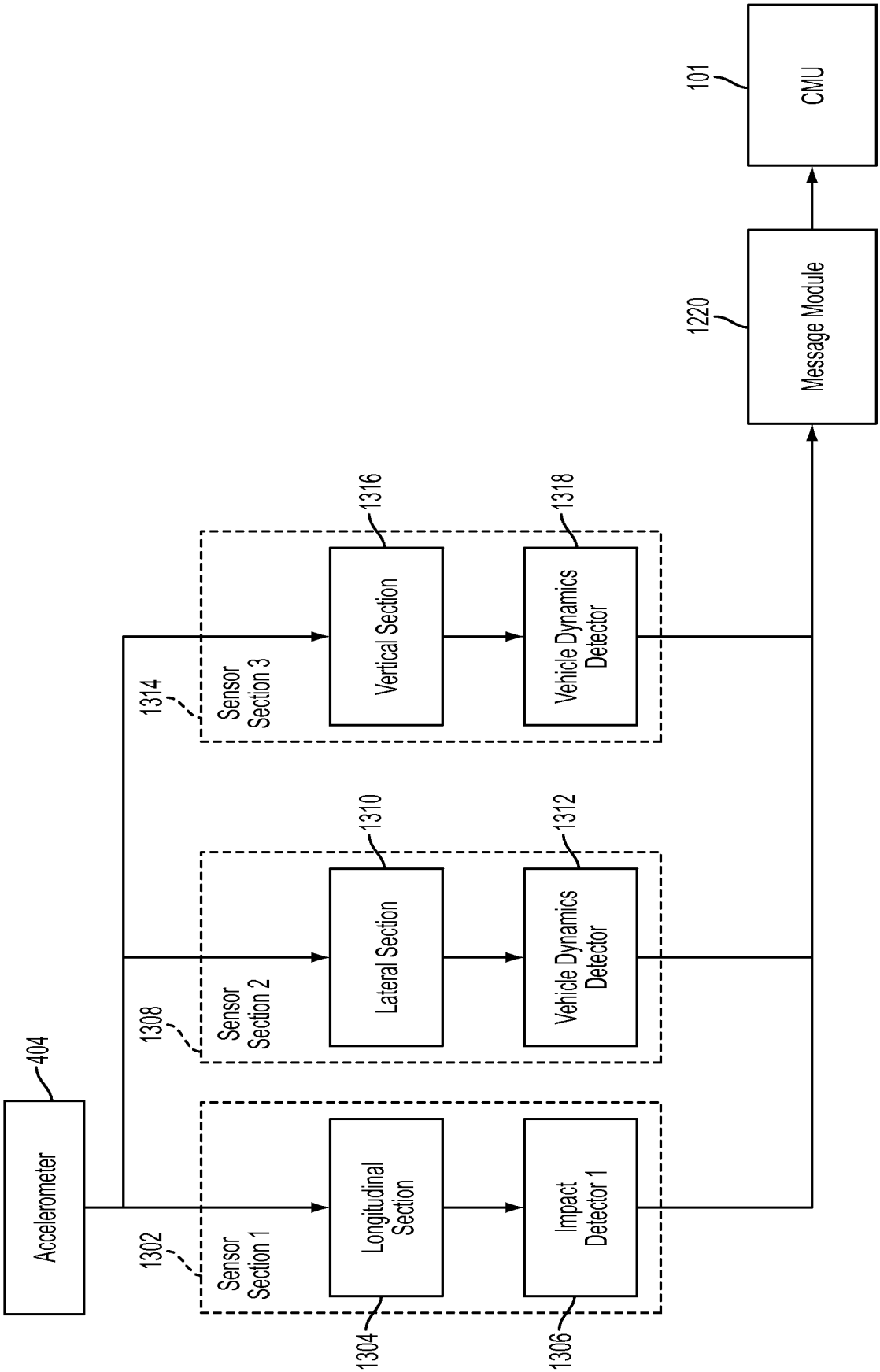

Accelerometer
404
Sensor Section 1
1302
Longitudinal Section
1304
Impact Detector 1
1306
Sensor Section 2
1308
Lateral Section
1310
Vehicle Dynamics Detector
1312
Sensor Section 3
1314
Vertical Section
1316
Vehicle Dynamics Detector
1318
Message Module
1220
CMU
101

FIG. 13

SUBSTITUTE SHEET (RULE 26)

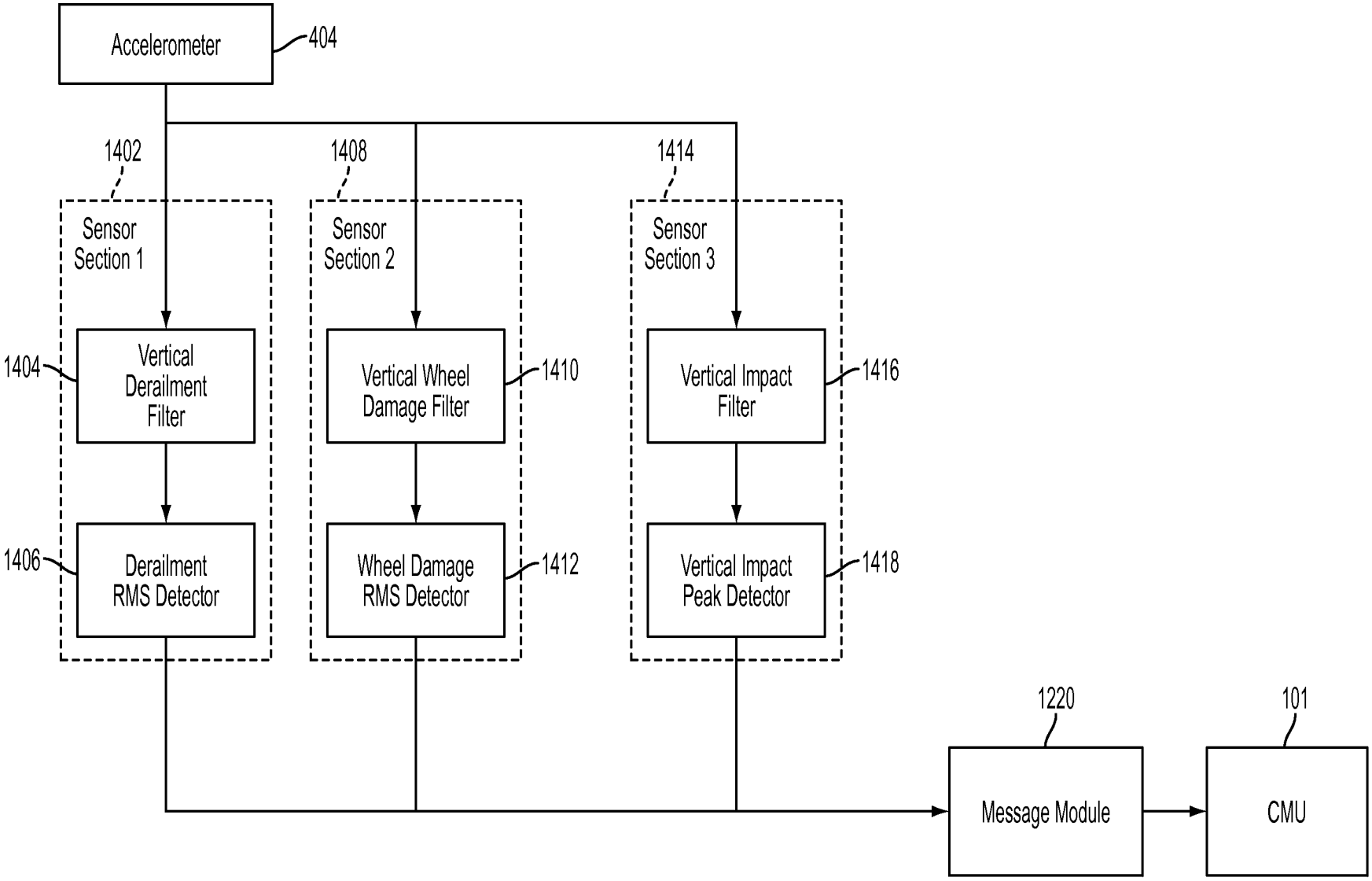


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/072380

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B61L 15/00 (2015.01)
CPC - B61L 15/0072 (2015.04)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B60T 17/22; B61L 15/00; G01K 7/02; G06F 19/00; G08B 21/18 (2015.01)
USPC - 246/169; 340/438, 870.16, 870.17; 374/152; 701/19, 20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - B60T 17/22, 17/228; B61K 9/04; B61L 15/0018, 15/0027, 15/0054, 15/0072, 15/0081, 2205/04 (2015.04) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar.
Search terms used: train, railcar, sensor, communication, wireless, management, analyze, operational, anomalies, remote, receiver, node, collect, thermo, temperature, data, parameter, network

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7,688,218 B2 (LEFEBVRE et al) 30 March 2010 (30.03.2010) entire document	1-30, 33-44, 46, 48-50, 54, 60-65
--		----------
Y		31, 32, 45, 47
Y	US 2009/0173840 A1 (BROWN et al) 09 July 2009 (09.07.2009) entire document	31, 32, 45, 47
A	US 8,370,006 B2 (KUMAR et al) 05 February 2013 (05.02.2013) entire document	1-55, 60-65
A	US 7,336,156 B2 (ARITA et al) 26 February 2008 (26.02.2008) entire document	1-55, 60-65
A	US 2007/0241610 A1 (SMITH) 18 October 2007 (18.10.2007) entire document	1-55, 60-65

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 April 2015	27 APR 2015
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/072380

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

SEE CONTINUATION SHEET ATTACHED

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-55, 60-65

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

CONTINUATION OF BOX III

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I, claims 1-55, 60-65 are drawn to a remote receiver.
Group II, claim 56 is drawn to mesh networks.
Group III, claims 57-59 are drawn to a wireless sensor node.

The inventions listed in Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, detecting operational anomalies on a train comprising communicating a message to a remote receiver when an anomaly is detected, are not present in Groups II or III; the special technical features of Group II, a system detecting operational anomalies on a train comprising, train-based mesh network, railcar-based mesh networks, a distributed complex event processing engine, are not present in Groups I or III; and the special technical features of Group III, wireless sensor node comprising a protective housing, a power source, an accelerometer, and an electrical circuitry, are not present in Groups I or II.

Groups I-III share the technical features of sensors located on railcars. However, these shared technical features do not represent a contribution over the prior art. Specifically, US 2012/0046811 A1 to Murphy et al., is in the field of railcar handbrake monitor (Abstract) and teaches of sensors located on railcars (Para. [0032], railcar 10 provided with a motion detection device 72 which can include motion sensors, tilt sensors).

Groups I and II share the technical features of communication management units mounted railcars and sensors located on railcars. Specifically, US 2012/0046811 A1 to Murphy et al., is in the field of railcar handbrake monitor (Abstract) and teaches of communication management units mounted railcars, and sensors located on railcars (Para. [0032], railcar 10 provided with a motion detection device 72 located in the CMU 70 [communication management unit] which can include motion sensors, tilt sensors).

Since none of the special technical features of the Groups I-III inventions are found in more than one of the inventions, unity is lacking.

PTO/AIA/80 (07-12)
Approved for use through 11/30/2014. OMB 0651-0035
U.S. Patent and Trademark Office; U.S DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

☒ Practitioners associated with Customer Number: 29880

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignments documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

☐ The address associated with Customer Number:

OR

☐	Firm or Individual Name			
	Address			
	City		State	Zip
	Country			
	Telephone		Email	

Assignee Name and Address: Amsted Rail Company, Inc.
311 South Wacker Drive
Chicago, IL 60602

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be Filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of The practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record
The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature	Edward J Brosius	Date	4-30-2015
Name	Edward Brosius	Telephone	312-819-8482
Title	SECRETARY		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: AMSTED RAIL COMPANY, INC.

Application No./Patent No.: US National Phase of PCT/US14/72380 Filed/Issue Date: 24 June 2016

Titled: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

Amsted Rail Company, Inc., a corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: _____ To: _____

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

2. From: _____ To: _____

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☑ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/gah/	24 June 2016
Signature	Date
Gary A. Hecht	36826
Printed or Typed Name	Title or Registration Number

[Page 2 of 2]

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ASSIGNMENT OF INVENTION

In consideration of the payment by ASSIGNEE to ASSIGNOR(S) of the sum of One Dollar ($1.00) and for other good and valuable consideration, the receipt of which is hereby acknowledged,

ASSIGNOR(S):

Name	Address
William D. LeFebvre	1145 Saint Finegan Drive West Chester, PA 19382
Andrew H. Martin	926 Pine View Drive West Chester, PA 19380
Francis James Cooper	1581 General Patton Drive Downingtown, PA 19335
Rachel W. Adamec	602 Middleton Place Norristown, PA 19403

hereby confirm that they have sold, assigned and transferred as of December 24, 2013, and hereby do sell, assign and transfer to:

ASSIGNEE:

Name	Address
Amsted Rail Company, Inc.	311 South Wacker Drive, Suite 5300, Chicago, IL 60606

and the successors, assigns and legal representatives of the ASSIGNEE, entire right, title and interest for the United States and its territorial possessions, and in all foreign countries, including all rights to claim priority, in and to the invention entitled:

System and Method for Detecting Operational Anomalies In Train Consists and Railcars

invented by William LeFebvre, Andrew H. Martin, Francis James Cooper and Rachel W. Adamec and which is found in:

- ☐ the U.S. patent application executed on even date herewith;
- ☐ the U.S. patent application executed on ;
- X the U.S. patent application no.: 61/920,700 filed: December 24, 2013
- X the International Application no. PCT/US2014/072380 filed: December 24, 2014
- ☐ the U.S. patent no. issued on;

and in and to all Non-Provisional and International Applications claiming priority therefrom, and all Letters Patent, both foreign and domestic, to be obtained for said invention by the aforesaid Non-Provisional and International Applications claiming priority therefrom , and all continuation, division, renewal, continuation-in-part or substitute of said Non-Provisional Applications, and as to Letters Patent and any reissue or re-examination thereof, and to any legal equivalent thereof in a foreign country, including, the right to apply for patents and inventor certificates in respect thereof, the right to claim priority, and all patents, patents of addition, utility models, patents of importation, revalidation patents and inventor certificates which may be granted throughout the world in respect of the invention.

ASSIGNOR(S) hereby authorizes ASSIGNEE or its legal representative to insert in this instrument the filing date and serial number of said application or any other information that may be necessary or

desirable in order to comply with the rules of the U.S. Patent and Trademark Office for the recordation of this document.

ASSIGNOR(S) hereby covenants that no assignment, sale, agreement or encumbrance has been or will be made or entered into which would conflict with this assignment.

ASSIGNOR(S) further covenants and agrees that ASSIGNEE will, upon its request, be provided promptly with all pertinent facts and documents relating to said invention and said Letters Patent and legal equivalents as may be known and accessible to ASSIGNOR(S), and that ASSIGNOR(S) will, at ASSIGNEE's expense, testify as to the same in any interference, litigation or proceeding related thereto and will promptly execute and deliver to ASSIGNEE, its assigns or its legal representatives, without further or additional consideration, any and all papers, instruments or affidavits required, render all necessary assistance, and do such additional acts as ASSIGNEE may deem necessary or desirable, to apply for, obtain, maintain, issue and enforce said application, said invention and said Letters Patent and said equivalents thereof which may be necessary or desirable to carry out the purposes thereof.

ASSIGNOR(S) hereby authorize and request the Commissioner of Patents and Trademarks to issue any and all United States Letters Patent referred to above to ASSIGNEE of the entire right, title and interest in and to the same, for ASSIGNEE's sole use and benefit, and for the use and benefit of ASSIGNEE's legal representatives and successors, to the full end of the term for which such Letters Patent may be granted, as fully and entirely as the same would have been held by ASSIGNOR(S) had this assignment and sale not been made.

The parties agree that the foregoing covenants and obligations shall bind and inure to the benefit of the heirs, assigns and legal representatives of both parties.

Name: _____
William D. LeFebvre

Date: 9/14/15

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Debra J Winkler, Notary Public
West Chester Borough, Chester County
My Commission Expires February 17, 2017

State of Pennsylvania
County of Chester

Before me this 14th day of September 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

_____
Notary Public

Name: _____ Date: 9/14/15
Andrew H. Martin

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Debra J Winkler, Notary Public
West Chester Borough, Chester County
My Commission Expires February 17, 2017

State of Pennsylvania

County of Chester

Before me this 14th day of September 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

_____
Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Debra J Winkler, Notary Public
West Chester Borough, Chester County
My Commission Expires February 17, 2017

Name: _____ Date: 9/14/15
Francis James Cooper

State of Pennsylvania

County of Chester

Before me this 14th day of September 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

_____
Notary Public

Name: _____ Date: _____
Rachel W. Adamec

State of

County of

Before me this _____ day of _____ 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

_____
Notary Public

ASSIGNMENT OF INVENTION

In consideration of the payment by ASSIGNEE to ASSIGNOR(S) of the sum of One Dollar ($1.00) and for other good and valuable consideration, the receipt of which is hereby acknowledged,

ASSIGNOR(S):

Name	Address
William D. LeFebvre	1145 Saint Finegan Drive West Chester, PA 19382
Andrew H. Martin	926 Pine View Drive West Chester, PA 19380
Francis James Cooper	1581 General Patton Drive Downingtown, PA 19335
Rachel W. Adamec	602 Middleton Place Norristown, PA 19403

hereby confirm that they have sold, assigned and transferred as of December 24, 2013, and hereby do sell, assign and transfer to:

ASSIGNEE:

Name	Address
Amsted Rail Company, Inc.	311 South Wacker Drive, Suite 5300, Chicago, IL 60606

and the successors, assigns and legal representatives of the ASSIGNEE, entire right, title and interest for the United States and its territorial possessions, and in all foreign countries, including all rights to claim priority, in and to the invention entitled:

System and Method for Detecting Operational Anomalies in Train Consists and Railcars

invented by William LeFebvre, Andrew H. Martin, Francis James Cooper and Rachel W. Adamec and which is found in:

☐ the U.S. patent application executed on even date herewith;
☐ the U.S. patent application executed on ;
X the U.S. patent application no.: 61/920,700 filed: December 24, 2013
X the International Application no. PCT/US2014/072380 filed: December 24, 2014
☐ the U.S. patent no. issued on;

and in and to all Non-Provisional and International Applications claiming priority therefrom, and all Letters Patent, both foreign and domestic, to be obtained for said invention by the aforesaid Non-Provisional and International Applications claiming priority therefrom , and all continuation, division, renewal, continuation-in-part or substitute of said Non-Provisional Applications, and as to Letters Patent and any reissue or re-examination thereof, and to any legal equivalent thereof in a foreign country, including, the right to apply for patents and inventor certificates in respect thereof, the right to claim priority, and all patents, patents of addition, utility models, patents of importation, revalidation patents and inventor certificates which may be granted throughout the world in respect of the invention.

ASSIGNOR(S) hereby authorizes ASSIGNEE or its legal representative to insert in this instrument the filing date and serial number of said application or any other information that may be necessary or

desirable in order to comply with the rules of the U.S. Patent and Trademark Office for the recordation of this document.

ASSIGNOR(S) hereby covenants that no assignment, sale, agreement or encumbrance has been or will be made or entered into which would conflict with this assignment.

ASSIGNOR(S) further covenants and agrees that ASSIGNEE will, upon its request, be provided promptly with all pertinent facts and documents relating to said invention and said Letters Patent and legal equivalents as may be known and accessible to ASSIGNOR(S), and that ASSIGNOR(S) will, at ASSIGNEE's expense, testify as to the same in any interference, litigation or proceeding related thereto and will promptly execute and deliver to ASSIGNEE, its assigns or its legal representatives, without further or additional consideration, any and all papers, instruments or affidavits required, render all necessary assistance, and do such additional acts as ASSIGNEE may deem necessary or desirable, to apply for, obtain, maintain, issue and enforce said application, said invention and said Letters Patent and said equivalents thereof which may be necessary or desirable to carry out the purposes thereof.

ASSIGNOR(S) hereby authorize and request the Commissioner of Patents and Trademarks to issue any and all United States Letters Patent referred to above to ASSIGNEE of the entire right, title and interest in and to the same, for ASSIGNEE's sole use and benefit, and for the use and benefit of ASSIGNEE's legal representatives and successors, to the full end of the term for which such Letters Patent may be granted, as fully and entirely as the same would have been held by ASSIGNOR(S) had this assignment and sale not been made.

The parties agree that the foregoing covenants and obligations shall bind and inure to the benefit of the heirs, assigns and legal representatives of both parties.

Name: _____ Date: _____
William D. LeFebvre

State of

County of

Before me this _____ day of _____ 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

_____
Notary Public

Name: _____ Date: _____
Andrew H. Martin

State of

County of

Before me this _____ day of _____ 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

_____
Notary Public

Name: _____ Date: _____
Francis James Cooper

State of PA

County of Montgomery

Before me this 16th day of September 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
SUDHA JAIN
Notary Public
LOWER PROVIDENCE TWP, MONTGOMERY CNTY
My Commission Expires Aug 13, 2018

_____
Notary Public

Name: _____ Date: 16 Sept 2015
Rachel W. Adamec

State of PA

County of Montgomery

Before me this 16th day of September 2015, personally appeared the above named individual, to me known to be the person who is described in, and who executed the foregoing instrument and acknowledged to me that he/she executed the same of his/her own free will for the purposes therein expressed.

Sudha Jain
_____
Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
SUDHA JAIN
Notary Public
LOWER PROVIDENCE TWP, MONTGOMERY CNTY
My Commission Expires Aug 13, 2018

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Filer:	Gary A. Hecht/Deanna M. McGregor
Attorney Docket Number:	P37056A US (37659.00060)

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
National Stage Fee	1631	1	280	280
Natl Stage Search Fee - U.S. was the ISA	1641	1	120	120
National Stage Exam - all other cases	1633	1	720	720
Pages:				
Claims:				
Claims in excess of 20	1615	11	80	880
Independent claims in excess of 3	1614	1	420	420
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**2420**

Electronic Acknowledgement Receipt

EFS ID:	26165907
Application Number:	15108065
International Application Number:	PCT/US2014/072380
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht/Deanna M. McGregor
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	24-JUN-2016
Filing Date:	
Time Stamp:	14:32:01
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$2420
RAM confirmation Number	062716INTEFSW14332700
Deposit Account	5690
Authorized User	Deanna McGregor

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	371_Transmittal_Letter_037659_00060.pdf	221674 74678b1d2ad9a43e58bbb070e6da8c1f2b8efa81	no	4
Warnings:					
Information:					
2	Oath or Declaration filed	Declarations_037659_00060.pdf	2734096 b558be3d8e1049805e5dd4a48cd4eccedb7820fa	no	8
Warnings:					
Information:					
3		Prelim_Amendment_037659_00060.pdf	56504 20fe97e4114021f4d4bc2cb2719773d8e0c86af4	yes	16

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Preliminary Amendment	1	1
	Claims	2	15
	Applicant Arguments/Remarks Made in an Amendment	16	16

Warnings:					
Information:					
4	Application Data Sheet	ADS_037659_00060.pdf	1819589 7e2aae1506e150e391be81e00b14a6ae99e3d928	no	8
Warnings:					
Information:					
5		Spec_037659_00060.pdf	3602752 7d7c8b041fdb2c57e0e2641bf7ad6024bccaf2a4	yes	60

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Abstract	1	2

	Specification		3		32
	Claims		33		43
	Drawings-only black and white line drawings		44		57
	Documents submitted with 371 Applications		58		60
Warnings:					
Information:					
6	Power of Attorney	POA_037659_00060.pdf	162460 09546db1aa3552acf9446ab7b6874fdc840eb242	no	1
Warnings:					
Information:					
7	Assignee showing of ownership per 37 CFR 3.73	3_73c_Statement_037659_00060.pdf	120698 a93aa52b422b14bf5fd2107a80447af1704b17fb	no	3
Warnings:					
Information:					
8	Assignee showing of ownership per 37 CFR 3.73	Assignments_037659_00060.pdf	533838 fbbb7279357339d401fb73bc449236cae70665c6	no	6
Warnings:					
Information:					
9	Fee Worksheet (SB06)	fee-info.pdf	38762 136997f55d7368b4141cbbf3659441efa0c13b1c	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	9290373		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

679588

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

January 25, 2015

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: *61/920,700*
FILING DATE: *December 24, 2013*
RELATED PCT APPLICATION NUMBER: *PCT/US14/72380*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US61/920,700*

Certified by

David J. Kappos

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

PTO/AIA/14 (12-13)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056 US 037659.00054
	Application Number	
Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	William		LeFebvre	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	West Chester	State/Province	PA	Country of Residence i	US

Mailing Address of Inventor:

Address 1	823 General Howe Drive		
Address 2			
City	West Chester	State/Province	PA
Postal Code	19382	Country i	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Andrew		Martin	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	West Chester	State/Province	PA	Country of Residence i	US

Mailing Address of Inventor:

Address 1	506 Oak Circle		
Address 2			
City	West Chester	State/Province	PA
Postal Code	19380	Country i	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

PTO/AIA/14 (12-13)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056 US 037659.00054
	Application Number	
Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars	

☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	29880		
Email Address	ipdocket@foxrothschild.com	Add Email	Remove Email

Application Information:

Title of the Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars		
Attorney Docket Number	P37056 US 037659.00054	**Small Entity Status Claimed**	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		**Suggested Figure for Publication (if any)**	

Filing By Reference :

Only compete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	29880		

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056 US 037659.00054
	Application Number	
Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the application number blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) [i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

			Remove
Application Number	Country [i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

PTO/AIA/14 (12-13)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056 US 037659.00054
	Application Number	
Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars	

Authorization to Permit Access:

☐ Authorization to Permit Access to the Instant Application by the Participating Offices

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here. ☒

Organization Name	Amsted Rail Company, Inc.

PTO/AIA/14 (12-13)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056 US 037659.00054
	Application Number	
Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars	

Mailing Address Information:			
Address 1	311 South Wacker Drive		
Address 2	Suite 5300		
City	Chicago	**State/Province**	IL
Country i	US	Postal Code	60606
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not subsitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication . An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

PTO/AIA/14 (12-13)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	P37056 US 037659.00054
	Application Number	
Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars	

Signature:

Remove

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications

Signature	/gah/			Date (YYYY-MM-DD)	2013-12-24
First Name	Gary A.	Last Name	Hecht	Registration Number	36826

Additional Signature may be generated within this form by selecting the Add button. Add

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (11-08)
Approved for use through 05/31/2015. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 — Remove

Given Name	Middle Name	Family Name	City	State	Country
William		LeFebvre	West Chester	PA	US

Inventor 2 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Andrew		Martin	West Chester	PA	US

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Title of Invention	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars
Attorney Docket Number (if applicable)	P37056 US 037659.00054

Correspondence Address

Direct all correspondence to (select one):

◉ The address corresponding to Customer Number	○ Firm or Individual Name
Customer Number	29880

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

- ◉ No.
- ○ Yes, the invention was made by an agency of the United States Government. The U.S. Government agency name is:
- ○ Yes, the invention was under a contract with an agency of the United States Government. The name of the U.S. Government agency and Government contract number are:

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (11-08)
Approved for use through 05/31/2015. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

Entity Status
Applicant asserts small entity status under 37 CFR 1.27 or applicant certifies micro entity status under 37 CFR 1.29

- ○ Applicant asserts small entity status under 37 CFR 1.27
- ○ Applicant certifies micro entity status under 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
- ◉ No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/gah/			Date (YYYY-MM-DD)	2013-12-24
First Name	Gary A.	Last Name	Hecht	Registration Number (If appropriate)	36826

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

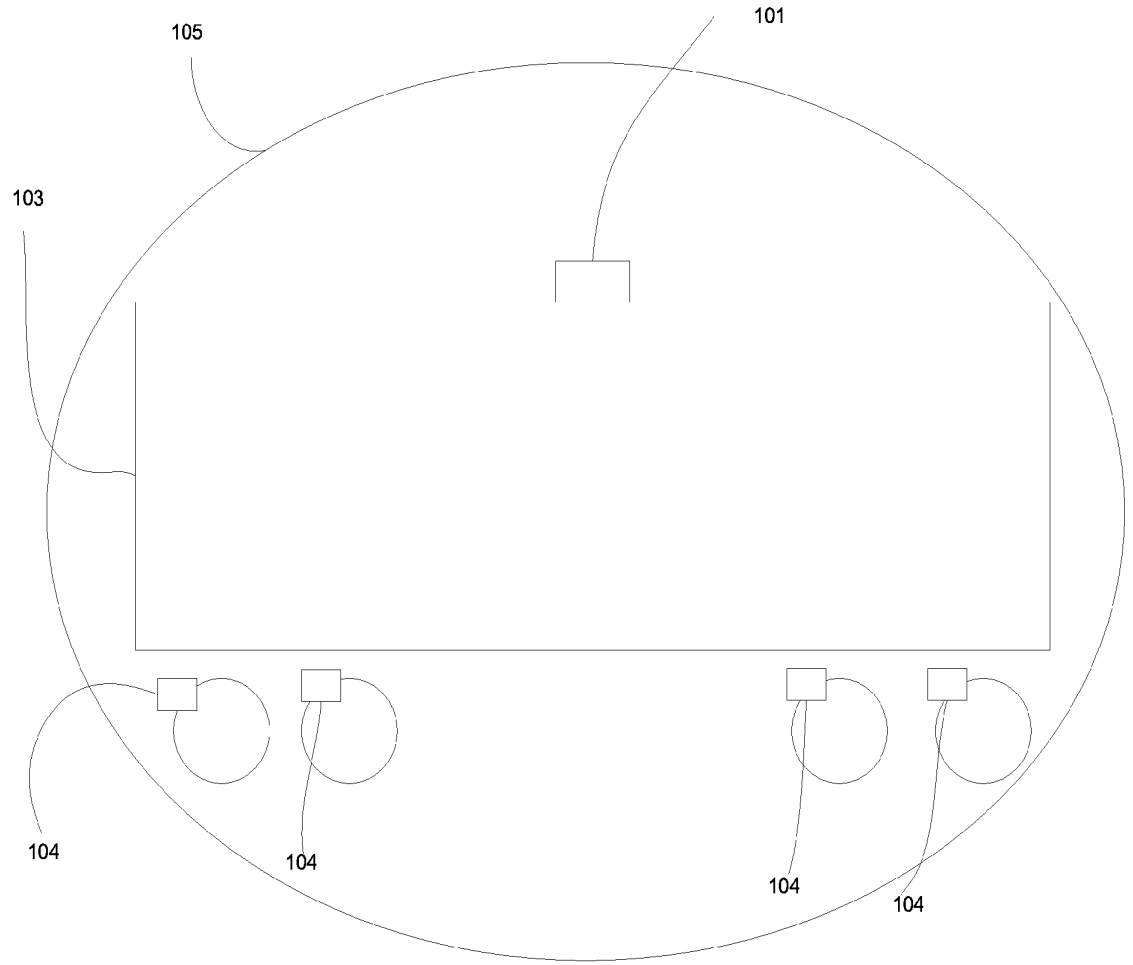
Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or paten. Accordingly, pursuant to the requirements of the Act, please be advised that : (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, t o a n other federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Figure 1



101 – communication management unit
103 - railcar
104 – wireless sensor nodes
105 – wireless mesh communication network

Figure 2

101 – communication management unit
102 – powered wireless gateway device
103 - railcar
104 – wireless sensor nodes
105 – wireless mesh communication network
106 – transmission to wireless powered gateway device
107 – intra-train wireless mesh communication network
108 - locomotive

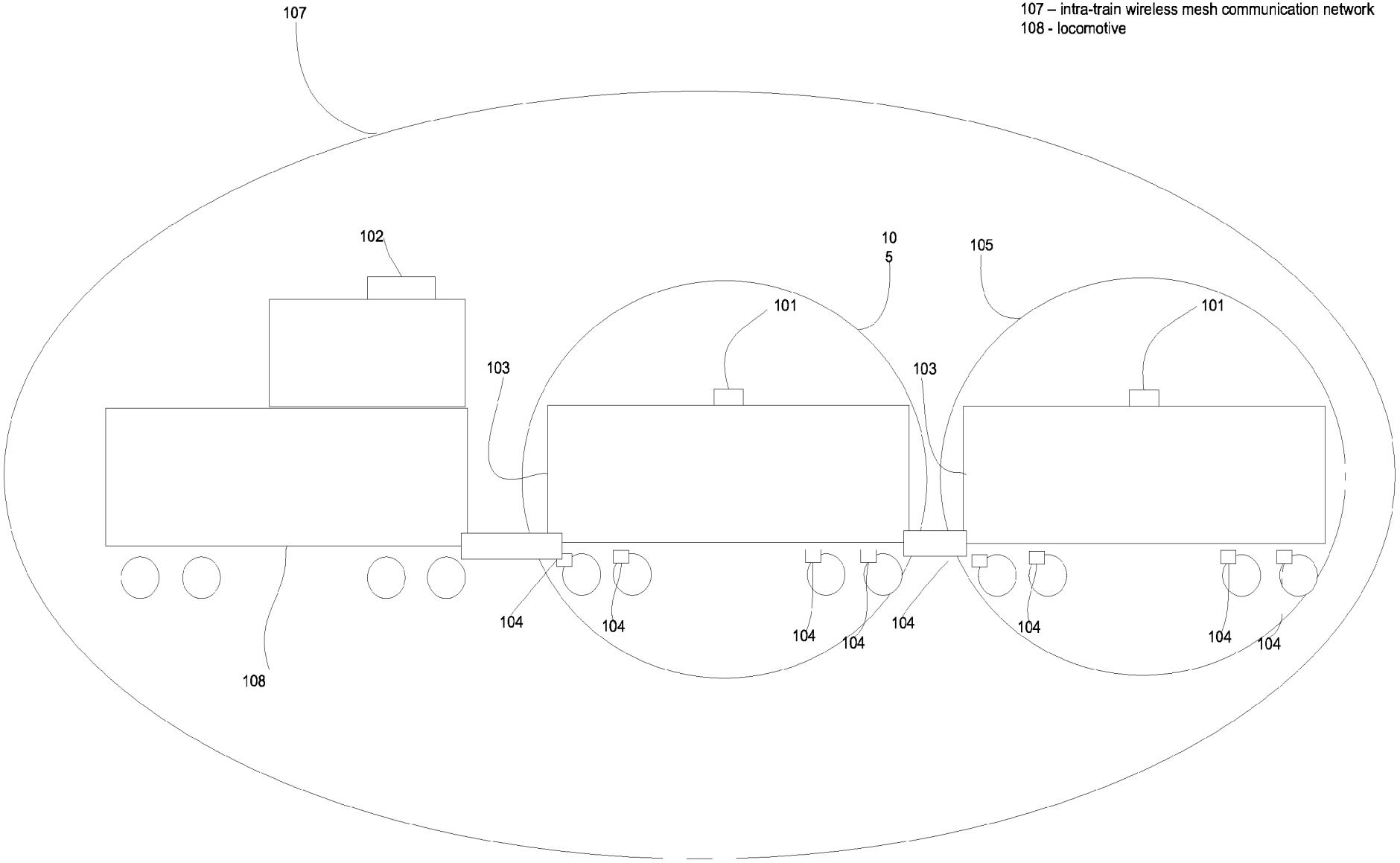
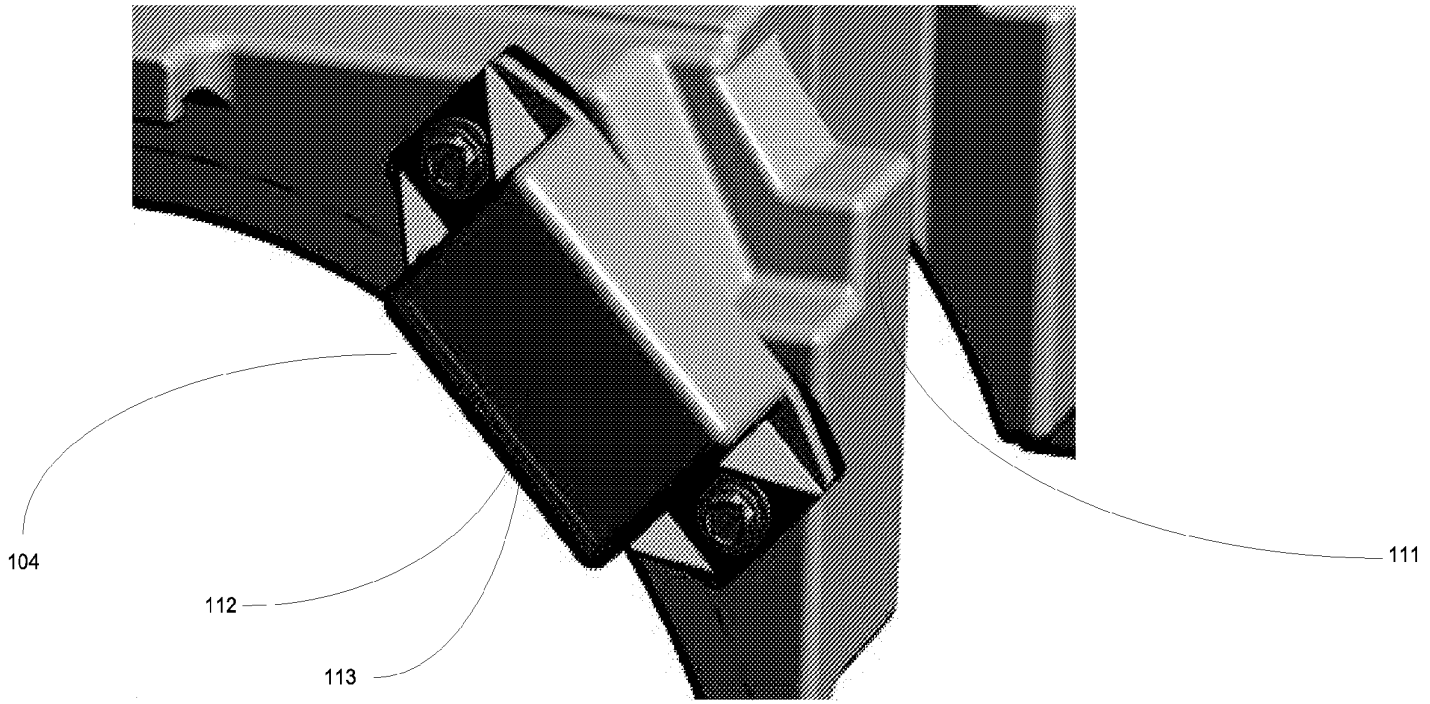
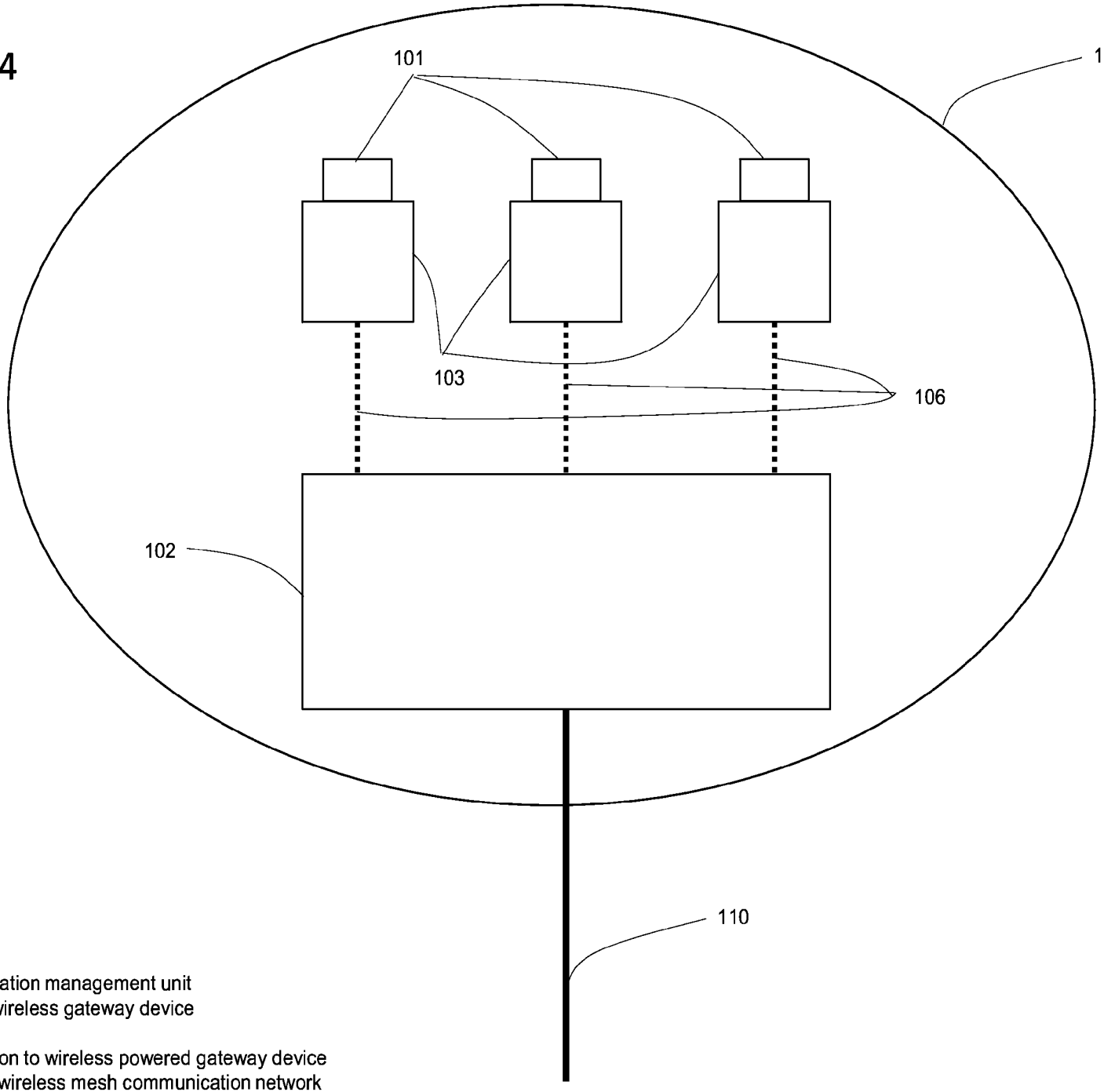


Figure 3



104 – wireless sensor node
111 – roller bearing adapter
112 – temperature sensor inside wireless sensor node **104**
113 – accelerometer inside wireless sensor node **104**

Figure 4



101 – communication management unit
102 – powered wireless gateway device
103 – railcar
106 – transmission to wireless powered gateway device
107 – intra-train wireless mesh communication network
110 – local area network / wifi

Title: System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars

Inventors: William LeFebvre, Andrew Martin

Assignee: Amsted Rail Company, Inc.

Drawings

Figure 1 is a schematic of a railcar **103** equipped with a communication management unit (CMU) **101** and a wireless sensor nodes **104** installed on roller bearing adapters **111** of each wheel of a railcar **103**.

Figure 2 is a schematic of three railcars **103** each equipped with a CMU **101** and wireless sensor nodes **104** installed near the wheels of a railcar **103** and a powered wireless gateway device **102** wherein the CMU **101** and wireless sensor nodes **104** transmit data to the powered wireless gateway device **102**.

Figure 3 shows a roller bearing adapter **111** and a wireless sensor node **104** attached thereto.
Figure 4 is diagram of a communication system **105** and a framework of an intra-train wireless mesh communication network **107** and a local area network **110**.

Need

Known monitoring of wheel to rail interactions on trains has been managed primarily through the use of Wayside Detectors, which monitor the temperature of railcar bearings and Wheel Impact Load Detectors (WILD), which monitor impacts of wheels on the rails. These detectors are installed at fixed points in the rail network.

While these methods have provided railroad operators with improved performance since their introduction, these detectors lack the benefits of a dynamic wireless network capable of transmitting information and data such as when a railcar **103** derails, a railcar **103** location, a condition of the bearings and wheels when not in range of detectors, and wheel damage. Further, these prior methods do not provide a mechanism to communicate operations alerts to an operations center or the locomotive **108** that can be actioned in the event of a problem or a potential problem.

Derailments are disruptive to the operations of a railroad. While most are relatively minor, there is a potential that they could be dangerous. For example, a railcar **103** can derail when the temperature of a bearing rises to a point where it seizes and causes the wheel not to turn, which could damage the wheel. When a railcar **103** derails, a wheel or wheels leave the track, which can cause damage to the said wheel or wheels and other railcar **103** components, the rails, and rail ties.

Railroads can benefit from early detection of a bearing or wheel impact problems on a railcar **103**, which can save time, financial resources, and decrease derailment risk by proactively monitoring and maintaining bearings and wheels.

The system presented here describes a solution consisting of a wireless mesh network communicating **105** the length of a train, delivering information about the railcars **103** to a locomotive **108** and to a railroad operations center. This information can be as simple as what railcars **103** are in the train through to alerts generated by a wireless sensor node **104** or a plurality of said wireless sensor nodes **104** acting on an individual railcar **103** reporting a bearing temperature, a wheel to rail impacts and a derailment.

System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars consists of:

An intra- train wireless mesh communication network system **107** using a 6LowPAN time synchronized wireless mesh network to provide bi-directional communication a railcar **103** or a plurality of railcars **103** in a train to a locomotive **108**.

A Powered Wireless Gateway device **102** to manage the intra-train wireless mesh communication network **107** and communicate alerts from the individual railcars **103** to the locomotive engineer or to other train management systems.

A Powered Wireless Gateway device **102** capable of receiving multiple sensor alerts or events from the individual railcars **103** and making an inference about performance of a train.

A Powered Wireless Gateway device **102** capable of receiving information from an external control center or data system that specifies the railcars **103** that should be in the train allowing only those railcars **103** to join and reporting any railcars **103** that are absent.

A Communication Management Unit (CMU) **101** on each railcar **103** capable of being a wireless node in the intra-train wireless mesh communication network **107** and being able to send messages to the locomotive **108**.

A CMU **101** on each railcar capable of using built-in sensors and/or managing a wireless sensor node **104** network on the railcar **103** to generate messages that need to be sent to the locomotive**108**.

A CMU **101** on each railcar **103** capable of supporting an optional GNSS sensor to determine location, direction or speed of the railcar **103**.

A CMU **101** on each railcar **103** capable of storing wireless sensor node **104** data or events that are not time critical and transmitting from the railcar **103** to a data center through a wide area communication system (such as a cellular network) or when in range of a yard based Wi-Fi network **110**.

A Wireless Sensor Node **104** capable of forming part of a wireless mesh communication network **105** on a railcar **103**.

A Wireless Sensor Node **104** containing a temperature sensor **112** and an accelerometer **113**.

A Wireless Sensor Node **104** containing other sensors.

Detailed Brief Description

A communications management unit (CMU) **101** installed on a railcar **103** uses a wireless mesh communication network **105** to transmit data **106** to a powered wireless gateway device **102** in a locomotive **108** or to a remote control center. Said CMU **101** supports a wireless sensor **104** node or a plurality of wireless sensor nodes **104.** The mesh communication network architecture is a foundational building block of the IEC 62591 international wireless standard as well as the ISA100.11a standard from the International Society of Automation. Said CMU **101** supports four functions to 1) manage a low-power wireless mesh communication network **105** on a railcar **103**, 2) consolidate data from a wireless sensors node **104** or a plurality of wireless sensor nodes **104** in the wireless mesh communication network **105** and apply logic to the data in order to an generate alert to the locomotive **108** or the remote control center, 3) support wireless sensor nodes **104** within the said CMU **101** to monitor specific attributes of the

railcar **103** such as location, speed, accelerations and more; 4) support bi-directional communication to the locomotive **108** and the monitoring and control software system. The said CMU **101** allows wireless sensor nodes **104** to know precisely when to transmit, listen, or sleep. Message packet exchanges are synchronized so that no packets collide on the wireless mesh communication network **105**, and every packet is scheduled and synchronized for energy efficiency. Communication traffic on said network **105** is protected by end-to-end 128 bit AES-based encryption, message integrity checking, and device authentication.

A wireless intra-train wireless mesh communication network **107** overlaid on a train where each railcar **103** in said train is equipped with its own wireless mesh communication network **105**. The railcar **103** based wireless mesh communication network **105** continually monitors the CMU **101** and the wireless sensor nodes **104** to optimize the communication paths within the wireless mesh communication network **105** to find the routing that maximizes the performance at the same time minimizing the power drain by the CMU **101** and wireless sensor nodes **104** because a moving railcar **103** creates an ever changing wireless environment. Said wireless mesh communication network **107** uses an overlay wireless mesh network **105** to support low-power bi-directional communication throughout the train and the locomotive **108**. The overlay network **107** is composed of wireless transceivers embedded in each CMU **101**. It is capable of initiating a message on the wireless mesh communication network **105** or relaying a message from or to another CMU **101**. The intra-train mesh network **107** is managed by a powered wireless gateway device **102** installed in the locomotive **108**.

A wireless sensor node **104** uses a networking protocol to lower power consumption. It consists of a radio transceiver and an antenna which are integrated into a small high impact resistant enclosure. Each said wireless sensor node **104** is equipped with an ultra-low power microcontroller that allows sampling and extensive on-board computations including FFT's, filtering, and trending. The said node **104** is powered by a high energy density, low self-discharge lithium battery or batteries or a thermo electric generator. Each said wireless sensor node **104** is a router that is capable of communicating with any other wireless sensor node **104** on the same railcar **103** within communication range creating redundant communication paths around the same railcar **103**. The wireless mesh communication network **105** dynamically identifies the best path to route a message to maximize the use of paths that have good performance minimizing the time it takes for a message to pass through the network, and minimize the power drain on any individual wireless sensor node **104** routing a message. A communication path diversity protocol uses a time division scheme and frequency hopping to allow many wireless sensor nodes **104** to co-exist on the railcar **103** without interference.

A plurality of railcars **103** each equipped with a wireless mesh communication network **105** consisting of a CMU **101** and one wireless sensor node **104** or a plurality of wireless sensor nodes **104** can co-exist in close proximity within a rail yard or in a train without conflict.

The wireless sensor node **104** will include both an accelerometer **113** and a temperature sensor **112**. A product specification sheet for a suitable sensor node **104** is included at the end of this document. The said sensor **104** will be installed on a railcar **103** roller bearing adapter **111**. The temperature sensor **112** within said wireless sensor node **104** will monitor the temperature of the bearing and analyze for peaks, gradients and other temperature trends over pre-defined periods of time, which are often indicative of a potential failure of the bearing. Such failure can cause a derailment of one or more railcars **103**. The accelerometer **113** in said wireless sensor node **104** will monitor for the rate or force of vertical acceleration faults and changes in wheel to rail contact, all of which are indicative of a broken rail, derailment, running surface defect or wheel damage. The wireless sensor node **104** is installed on the outside face of the roller bearing adapter **111** such that it does not interfere with the typical operation of the bearing. A heuristic will be applied to data collected to determine an alert condition then send said alert to the locomotive **108** or the remote control center.

The powered wireless gateway device **102**, also sometimes referred to as a wireless network manager, is installed within a locomotive **108.** It is a data hub for all communication of real-time parameters from the railcar **103** through the train. The said gateway device **102** has a processor, a GPS module and a satellite or a cellular communication system, a power supply available from a locomotive **108** and a high capacity network manager. Each component in this system serves a role in maintaining and monitoring the intra-train wireless mesh communication network **107**. The high capacity network manager operates in the same way as the wireless mesh communication network **105** on the railcar **103**. An overlay network **107** is created independent of each railcar in the intra-train mesh communication network **107.**
Wide area communication is used to support messaging from a railcar **103** to an external location such as a locomotive **108** or a server-based monitoring and control system.

The CMU **101** supports communication to the locomotive **108** using an intra-train wireless mesh communication network **107**. Said network **107** acts as an overlay mesh on top of the railcar-based wireless mesh communication network **105**. Each network uses the same protocol and radio. The protocol has been designed so that many wireless mesh communication networks **105** can operate in close proximity.

The overlay wide area communication network **107** to the locomotive **108** is designed for reliable messaging of small alert messages or packets of data. Higher data volumes use an integrated quad-band cellular modem built in to the CMU **101**. Since this data is used for analyzing medium and long trends in railcar **103** performance it is not as time sensitive as the alert messages, and can be stored then forwarded when the railcar **103** is in an area with cellular coverage.

A powered wireless gateway device **102** installed on a locomotive **108** manages the intra-train wireless mesh communication network overlaid **107** on the train. Said device **102** collects railcar **103** or train data that can be stored or forwarded to a locomotive engineer and or is sent to a remote control center that manages the train.

A CMU installed on a railcar **103** collects data about the railcar **103** from wireless sensor nodes **104** installed on the railcar **103**. Wireless sensor nodes **104** transmit data to said CMU **101**. Said CMU **101** connects with the intra-train wireless mesh communication network **107** overlaid on the train that when connected transmits data to a powered wireless gateway device **102** installed on a locomotive **108**.

The data from the powered wireless gateway device **102** is filtered by an application programming interface (API) providing information pre-defined by an information user so that only the information the said user needs is provided to the said user.

The communication system where a CMU **101** provides the ability to control a wireless mesh communication network **105** and railcars **103**, associated or assigned to such intra-train wireless mesh communication network **107** within a locomotive **108** or train through a set of commands exposed by the API. The services provided by the API system provides the ability to receive event and status information from CMU **101** and wireless sensor nodes **104** installed on a railcar **103**. The application programming interfaces are registered to receive events asynchronously, or remote procedures can be called to retrieve information from the CMU **101** or wireless sensor nodes **104** in a manner where a CMU **101** or wireless sensor node **104** is sent a periodic or scheduled request by the API for the said CMU or said wireless sensors to send data back to the API. The API is exposed through a web service, and is accessible over the local area network **110** through an SSL connection and authenticated with a unique key reserved for each end user.

The API software is designed to provide methods consisting of commands to manage railcars **103** and locomotives **108** within, or outside, a rail yard where railcars **103** are managed by a railroad or other entity personnel. The API issues commands to the powered wireless gateway **102** that will wirelessly communicate with the CMU **101** on the railcars **103**, initiating the process to form the appropriate intra-train wireless mesh communication network **107**. Through the API, commands are also issued to the locomotive**108**, enabling the intra-train wireless mesh communication network **107** to be formed to match the train.

The API methods are exposed as web services using the secure HTTP protocol over SSL. The commands and functionality can be accessed on a locomotive **108** through a wired network connection or from the rail yard wirelessly. The said API and functionality is present in the rail yard powered wireless gateway **102** in order to make the system as flexible. This flexibility is required so the rail yard and locomotives **108** can be managed from one central location if necessary.

The full disclosures of U.S. patent publication 2010/0174428 filed January 11, 2010, U.S. patent publication 2012/0046811 filed August 23, 2010, U.S. patent application 13/842,427 filed March 15, 2013, and U.S. provisional application 61909899 filed on November 27, 2013 are incorporated herein by reference.

*****

Wireless Sensor Node Specifications

WSN-142 Dual Temperature and Accelerometer Sensor

The IONX WSN-142 Temperature and Accelerometer sensor is an upgraded version of the WSN-102 Temperature sensor in that it includes a three-axis accelerometer. This sensor is designed to wirelessly detect derailments and monitor wheel faults on freight railcars. The sensor can be used for a variety of functions where it is important to know impacts are occurring and their related frequency and force. A typical application is to mount the sensor on a railcar bearing adapter where it can measure the rate, force or change in wheel contact with the rail. It also can measure bearing temperature to detect increased temperature trending that often indicates potential failure, which could then cause a derailment. If the impacts forces exceed pre-defined thresholds, warnings can be issued automatically. With a configurable event engine in both the WSN and the upper level Communication Management Unit (CMU), various configurations are possible. The sensor is designed to withstand the harshest of operating environments. This flexible telematics solution can be deployed quickly and easily at an affordable price point.

KEY FEATURES

Programmable sample rate for temperature and accelerometer

Tri-axial accelerometer to measure impacts with programmable range, level event and energy event triggers

High/Low event detection for temperature and impacts

Delta temperature trending and delta high/low event detection

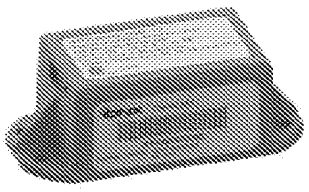
Customizable Event Engine for dynamic CMU control.

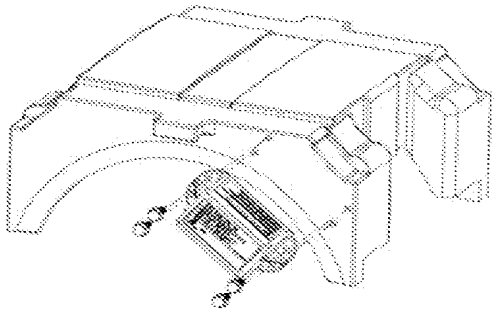
Firmware over-the-air (FOTA) upgrades for on demand feature upgrades.

Designed to withstand the harshest of operating environments. Environmentally sealed and railroad durable

Easy installation on most assets.

Five (5)+ year service life





PRODUCT ORDER REQUIREMENTS PER ASSET

One CMU-T5S, -T5X, -T6X, or -T7X.

Nine (9) WSN-102 with eight (8) on bearing adapters and one for ambient temperature

Monthly data service.

Activation.

Installation services and training are available.

For product information, contact either your Amsted Rail Sales Director or IONX at 484-653-2600 or email info@ionxlive.com. For the IONX Customer Support Center call 1-800-621-8442 or email SupportCenter@ionxlive.com.

515 S. Franklin Street, West Chester, PA 19382, USA
484-653-2600 www.ionxlive.com
ISO 9001: 2008 Certified

Wireless Sensor Node Specifications

WSN-142 Dual Temperature and Accelerometer Sensor

PHYSICAL Dimensions: 3.5 x 1.6 x 1.3 inches (6.0 x 4.0 x 3.5 cm) Weight: 200 g Housing: High performance engineered plastic	**INTEGRATED SENSORS** Tri-axial accelerometer • Range: 2g, 4g, 8g, 16g, 100g, 200g, 400g • Frequency:0 to 1600Hz bandwidth maximum • Accuracy: ±0.5dB Temperature accuracy: Typical ± 2°C; Ambient Temperature Sensor Accuracy: ±2 °C High sensitivity reed switch
POWER Quantity and Size: Two (2) AA-cell Type: 4.8 A-h nominal internal lithium thionyl chloride batteries	**DATA MANAGEMENT AND INTEGRATION** IONXlive – user web interface Optional interactive dashboards Standard and custom management reports
ENVIRONMENTAL STANDARDS Operating temperature: -40°F to 185°F (-40° to 85°C) Storage temperature: -40°F to 185°F (-40° to 85°C) Shock: M-1002; 15g peak, 11 ms pulse; Vibration: 2.5g peak, 5 mm Humidity: MIL810G & S5702 Salt Fog: MIL810G & S5702	**SAFETY CERTIFICATIONS** CE, FCC - Part 15B Industry Canada RoHS
COMMUNICATIONS Integrated radio and antenna (IEEE 802.15.4). Wireless Network Security 128-bit AES encryption, FIPS-197 certified. Wireless Network Reliability 99.9% Typical.	**MESSAGING MODES AND OPTIONS** Report on temperature deltas with location, date and time. Report on impacts exceeding pre-defined thresholds Customizable firmware over-the-air (FOTA) changes.
INTERFACE Not applicable	**PART NUMBERS** CMU: T5S, T5X, T6X, or T7X WSN-142: WSN-142-T

790-00014_A1 Pre-release; Datasheet is for informational purposes only. Specifications are subject to change without notice. **IONX makes no warranties expressed or implied, in this product specification document.**

515 S. Franklin Street, West Chester, PA 19382, USA
484-653-2600 www.ionxlive.com
ISO 9001: 2008 Certified

Electronic Acknowledgement Receipt	
EFS ID:	17754939
Application Number:	61920700
International Application Number:	
Confirmation Number:	8691
Title of Invention:	System and Method for Monitoring Wheel Damage and Detecting Derailments for Railcars
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht/Denise Grisack
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	P37056 US 037659.00054
Receipt Date:	24-DEC-2013
Filing Date:	
Time Stamp:	16:37:08
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$260
RAM confirmation Number	2052
Deposit Account	501943
Authorized User	HECHT, GARY

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	ADS.PDF	1290841 972a119a8514d968c4e96b6206b2c4d0afb1d2c4	no	7
Warnings:					
Information:					
2	Provisional Cover Sheet (SB16)	ProvCovSheet.PDF	1456997 0043ca2b9b951865042e606f0bd0dc890877680e	no	3
Warnings:					
Information:					
3	Drawings-only black and white line drawings	drawingsgah.pdf	65802 2c4e9e0ae82a8124050fccfd90609356eacd473d	no	4
Warnings:					
Information:					
4	Specification	Appcln.pdf	321208 37cdcf5875569cb7557b9f61c4755b5f2104892c	no	7
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	29690 20aaf00ac7c2d9cb559eeb6054b7d926adcc316c	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	3164538		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

DOCUMENT MADE AVAILABLE UNDER THE PATENT COOPERATION TREATY (PCT)

International application number:		**PCT/US2014/072380**
International filing date:		**24 December 2014 (24.12.2014)**
Document type:		**Certified copy of priority document**
Document details:	Country/Office:	**US**
	Number:	**61/920,700**
	Filing date:	**24 December 2013 (24.12.2013)**
Date of receipt at the International Bureau:		**26 January 2015 (26.01.2015)**

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a),(b) or (b-*bis*)

34, chemin des Colombettes
1211 Geneva 20, Switzerland
www.wipo.int

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

PCT/US14/72380
International Application No.

24 DECEMBER 2014 (24.12.14)
International Filing Date

PCT INTERNATIONAL APPLICATION
RO/US
Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* 037659.00056

Box No. I TITLE OF INVENTION

System and Method for Detecting Operational Anomalies In Train Consists and Railcars

Box No. II APPLICANT ☐ This person is also inventor

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

AMSTED RAIL COMPANY, INC.
311 South Wacker Drive
Suite 5300
Chicago, IL 60606
UNITED STATES OF AMERICA

Telephone No.

Facsimile No.

Applicant's registration No. with the Office

E-mail authorization: Marking one of the check-boxes below authorizes the receiving Office, the International Searching Authority, the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application to that e-mail address if those offices are willing to do so.

☐ as advance copies followed by paper notifications; or ☐ exclusively in electronic form (no paper notifications will be sent)

E-mail address:

State *(that is, country)* of nationality: US

State *(that is, country)* of residence: US

This person is applicant for the purposes of: ☒ all designated States ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

HECHT, Gary A.
Fox Rothschild LLP
997 Lenox Drive, Building 3
Lawrenceville, New Jersey 08648-2311
United States of America

Telephone No. (215) 299-2416

Facsimile No. (215) 299-2150

Agent's registration No. with the Office 36,826

E-mail authorization: Marking one of the check-boxes below authorizes the receiving Office, the International Searching Authority, the International Bureau and the International Preliminary Examining Authority to use the e-mail address indicated in this Box to send notifications issued in respect of this international application to that e-mail address if those offices are willing to do so.

☐ as advance copies followed by paper notifications; or ☒ exclusively in electronic form (no paper notifications will be sent).

E-mail address: ipdocket@foxrothschild.com

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

LEFEBVRE, William
1145 Saint Finegan Drive
West Chester, Pennsylvania 19382
United States of America

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☒ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

MARTIN, Andrew H.
926 Pine View Drive
West Chester, Pennsylvania 19380
United States of America

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☒ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

COOPER, Francis James
1581 General Patton Drive
Downington, Pennsylvania 19335
United States of America

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☒ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

ADAMEC, Rachel W.
602 Middleton Place
Norristown, Pennsylvania 19403
United States of America

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☒ inventor only *(If this check-box is marked, do not fill in below.)*

Applicant's registration No. with the Office

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Supplemental Box *If the Supplemental Box is not used, this sheet should not be included in the request.*

1. *If, in any of the Boxes, except Boxes Nos. VIII(i) to (v) for which a special continuation box is provided, **the space is insufficient** to furnish all the information: in such case, write "Continuation of Box No...." (indicate the number of the Box) and furnish the information in the same manner as required according to the captions of the Box in which the space was insufficient, in particular:*

(i) ***if more than one person is to be indicated as applicant and/or inventor** and no "continuation sheet" is available: in such case, write "Continuation of Box No. III" and indicate for each additional person the same type of information as required in Box No. III. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below;*

(ii) *if, in Box No. II or in any of the sub-boxes of Box No. III, the indication **"the States indicated in the Supplemental Box"** is checked: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the applicant(s) involved and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is applicant;*

(iii) *if, in Box No. II or in any of the sub-boxes of Box No. III, **the inventor or the inventor/applicant is not inventor for the purposes of all designated States**: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the inventor(s) and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is inventor;*

(iv) *if, in addition to the agent(s) indicated in Box No. IV, there are **further agents**: in such case, write "Continuation of Box No. IV" and indicate for each further agent the same type of information as required in Box IV;*

(v) *if, in Box No. VI, there are **more than three earlier applications whose priority is claimed**: in such case, write "Continuation of Box No. VI" and indicate for each additional earlier application the same type of information as required in Box No. VI.*

2. *If the applicant intends to make an indication of the wish that the international application be treated, in certain designated States, as an application for a patent of addition, certificate of addition, inventor's certificate of addition or utility certificate of addition: in such a case, write the name or two-letter code of each designated State concerned and the indication "**patent of addition**," "**certificate of addition**," "**inventor's certificate of addition**" or "**utility certificate of addition**," the number of the parent application or parent patent or other parent grant and the date of grant of the parent patent or other patent grant or the date of filing of the parent application (Rules 4.11(a)(i) and 49bis.1(a) or (b)).*

3. *If the applicant intends to make an indication of the wish that the international application be treated, in the United States of America, as a continuation or continuation-in-part of an earlier application: in such a case, write "United States of America" or "US" and the indication "**continuation**" or "**continuation-in-part**" and the number and the filing date of the parent application (Rules 4.11(a)(ii) and 49bis.1(d)).*

Continuation of Box No. IV:

Barrison, Flynn, 53,970 and Ma, Kenneth, 63,839

Box No. V DESIGNATIONS

The filing of this request **constitutes under Rule 4.9(a), the designation** of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.

However,

☐ DE Germany **is not designated** for any kind of national protection.

☐ JP Japan **is not designated** for any kind of national protection.

☐ KR Republic of Korea **is not designated** for any kind of national protection.

(The check-boxes above may only be used to exclude (irrevocably) the designations concerned if, at the time of filing or subsequently under Rule 26bis.1, the international application contains in Box No. VI a priority claim to an earlier national application filed in the particular State concerned, in order to avoid the ceasing of the effect, under the national law, of this earlier national application.)

Box No. VI PRIORITY CLAIM AND DOCUMENTS

The priority of the following earlier application(s) is hereby claimed:

Filing date of earlier application *(day/month/year)*	Number of earlier application	Where earlier application is:		
		national application: country or Member of WTO	regional application: regional Office	international application: receiving Office
item (1) 24 December 2013 (24.12.2013)	61/920,700	US		
item (2)				
item (3)				

☐ Further priority claims are indicated in the Supplemental Box.

Furnishing the priority document(s):

☒ The **receiving Office** is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application(s) was filed with the Office which, for the purposes of this international application, is the receiving Office)* identified above as:

☒ all items ☐ item (1) ☐ item (2) ☐ item (3) ☐ other, see Supplemental Box

☐ The **International Bureau** is requested to obtain from a digital library a certified copy of the earlier application(s) identified above, using, where applicable, the access code(s) indicated below *(if the earlier application(s) is available in it from a digital library):*

☐ item (1) access code _____ ☐ item (2) access code _____ ☐ item (3) access code _____ ☐ other, see Supplemental Box

Restore the right of priority: the receiving Office is requested to restore the right of priority for the earlier application(s) identified above or in the Supplemental Box as item(s) (_____). *(See also the Notes to Box No. VI; further information **must** be provided to support a request to restore the right of priority.)*

Incorporation by reference: where an element of the international application referred to in Article 11(1)(iii)(d) or (e) or a part of the description, claims or drawings referred to in Rule 20.5(a) is not otherwise contained in this international application but is completely contained in an earlier application whose priority is claimed on the date on which one or more elements referred to in Article 11(1)(iii) were first received by the receiving Office, that element or part is, subject to confirmation under Rule 20.6, incorporated by reference in this international application for the purposes of Rule 20.6.

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if more than one International Searching Authorities is competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA / US

Box No. IX CHECK LIST for EFS-Web filings – this sheet is only to be used when filing an international application with RO/US via **EFS-Web**

This international application **contains** the following:	Number of sheets
(a) request form PCT/RO/101 (including any declarations and supplemental sheets)	5
(b) description (excluding any sequence listing part of the description, see (f), below)	30
(c) claims	11
(d) abstract	1
(e) drawings (if any)	14
(f) sequence listing part of the description in the form of an **image file** (e.g. PDF)	
Total number of sheets (including the sequence listing part of the description **if filed as an image file**)	61

(g) Sequence listing part of the description

- ☐ Filed in the form of an **Annex C/ST.25 text file**
- ☐ WILL BE filed separately on physical data carrier(s), on the same day and in the form of an **Annex C/ST.25 text file**

Indicate type and number of physical data carrier(s)

This international application is **accompanied by** the following item(s) *(mark the applicable check-boxes below and indicate in right column the number of each item):*	Number of items
1. [X] fee calculation sheet	1
2. ☐ original separate power of attorney	
3. ☐ original general power of attorney	
4. ☐ copy of general power of attorney; reference number:	
5. ☐ priority document(s) identified in Box No. VI as item(s):	
6. ☐ Translation of international application into *(language):*	
7. ☐ separate indications concerning deposited microorganism or other biological material	
8. ☐ *(only where item (f) is marked in the left column)* copy of the sequence listing in electronic form (Annex C/ST.25 text file) not forming part of the international application but **furnished only for the purposes of international search** under Rule 13*ter*	
9. ☐ *(only where item (f) is marked in the left column)* a statement confirming that "the information recorded in electronic form submitted under Rule 13*ter* is identical to the sequence listing as contained in the international application" as filed via EFS-Web	
10. ☐ copy of results of earlier search(es)(Rule 12*bis*.1(a))	
11. ☐ other *(specify):*	

Figure of the drawings which should accompany the abstract:

Language of filing of the international application: English

Box No. X SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request)

/Kenneth Ma 63,839/
Kenneth Ma, Agent for Applicant(s)
FOX ROTHSCHILD LLP

Attorney Reg. No. (when applicable): 63,839

For receiving Office use only

1. Date of actual receipt of the purported international application: 24 DECEMBER 2014 (24.12.14)		2. Drawings:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:		☐ received:
4. Date of timely receipt of the required corrections under PCT Article 11(2):		☐ not received:
5. International Searching Authority (if two or more are competent): ISA / US	6. ☐ Transmittal of search copy delayed until search fee is paid.	

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

To:

HECHT, Gary, A.
Fox Rothschild LLP
997 Lenox Drive, Building 3
Lawrenceville, NJ 08648-2311
ÉTATS-UNIS D'AMÉRIQUE

Date of mailing *(day/month/year)*
25 September 2015 (25.09.2015)

Applicant's or agent's file reference
037659.00056

IMPORTANT NOTIFICATION

International application No.
PCT/US2014/072380

International filing date *(day/month/year)*
24 December 2014 (24.12.2014)

1. The following indications appeared on record concerning:

☐ the applicant ☒ the inventor ☐ the agent ☐ the common representative

Name and Address
COOPER, Francis, James
1581 General Patton Drive
Downington, PA 19335
United States of America

State of Nationality | State of Residence

Telephone No.

Facsimile No.

E-mail address

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
COOPER, Francis, James
1581 General Patton Drive
Downingtown, PA 19335
United States of America

State of Nationality | State of Residence

Telephone No.

Facsimile No.

E-mail address
☐ Notifications by e-mail authorized

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☐ the Authority(ies) specified for supplementary search
☐ the International Preliminary Examining Authority
☒ the designated Offices concerned
☐ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. +41 22 338 70 80

Authorized officer
Gevaux David
e-mail pt03.pct@wipo.int
Telephone No. +41 22 338 74 03

Form PCT/IB/306 (January 2009) 1/NAG44LT9NPZD30

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 July 2015 (02.07.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/100425 A1

(51) International Patent Classification:
B61L 15/00 (2006.01)

(21) International Application Number:
PCT/US2014/072380

(22) International Filing Date:
24 December 2014 (24.12.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/920,700 24 December 2013 (24.12.2013) US

(71) Applicant: **AMSTED RAIL COMPANY, INC.** [US/US]; 311 South Wacker Drive, Suite 5300, Chicago, IL 60606 (US).

(72) Inventors: **LEFEBVRE, William**; 1145 Saint Finegan Drive, West Chester, PA 19382 (US). **MARTIN, Andrew, H.**; 926 Pine View Drive, West Chester, PA 19380 (US). **COOPER, Francis, James**; 1581 General Patton Drive, Downington, PA 19335 (US). **ADAMEC, Rachel, W.**; 602 Middleton Place, Norristown, PA 19403 (US).

(74) Agents: **HECHT, Gary, A.** et al.; Fox Rothschild LLP, 997 Lenox Drive, Building 3, Lawrenceville, NJ 08648-2311 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

(57) Abstract: A system for monitoring railcar and tram consist operational parameters and detecting anomalies in the operation and condition thereof using sensors to feed data to a distributive complex event processing engine.

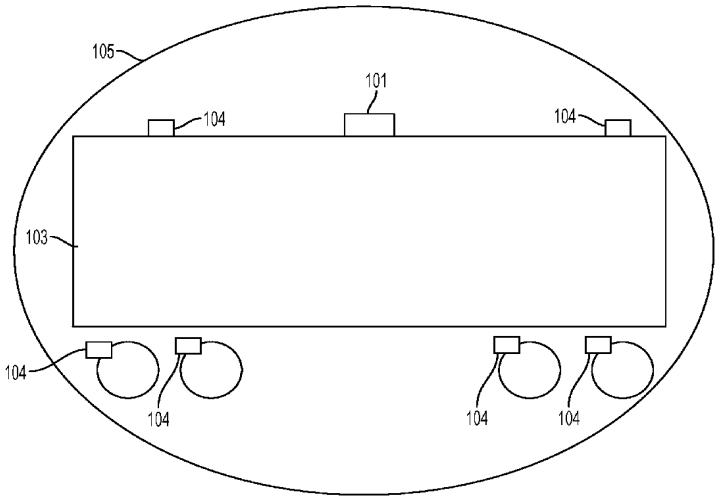


FIG. 1

WO 2015/100425 A1

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

Related Applications

[0001] The application claims the benefit of U.S. provisional application 61/920,700, filed December 24, 2013, the entirety of which is hereby incorporated herein by reference.

Field of the Invention

[0002] The present invention relates to the field of railcar and train safety management, and is specifically directed to a system and method for continuously collecting and analyzing operational parameters of railcars and train consists to detect anomalous operating conditions.

Background of the Invention

[0003] Current prior art monitoring of bearings and wheel to rail interactions on train consists has been managed primarily through the use of wayside detectors located throughout the rail system, which includes detectors for monitoring the temperature of railcar wheel bearings, and wheel impact load detectors which identify damaged wheels by monitoring impacts of wheels on the rails. These detectors are installed at fixed points in the rail network.

[0004] Since their introduction, these methods have provided railroad operators with information to improve railcar and train consist performance. However, these detectors lack the benefits of a wireless network capable of transmitting information and data regarding operational anomalies, such as when a railcar derails, the condition of the bearings and wheels when not in range of detectors, and wheel damage. Further, these prior methods do not provide a mechanism to continuously monitor assets at any location in the rail network.

[0005] Wheel damage in the railroad industry is responsible for significant maintenance costs related to the railcar wheels, railcar body, railcar components, rail tracks and rail ties. Wheels that are slid flat have an uneven section on the wheel where it comes into contact with the rail. As the wheel rotates this section creates an abnormal impact pattern, which can cause further damage to the wheel, damage to the railcar and damage to the rail and track structure.

[0006] Presently, however, there is no reliable system for continuously monitoring the temperature of wheel bearings or wheel to rail interactions where a wheel impact load detector is not installed on a section of rail or in the area between detectors. Accordingly, it is desirable to provide a system and method for the real-time, on-board monitoring of various operational parameters of a railcar and/or train consists, and for analyzing the readings in real time to predict or timely detect anomalous operational conditions.

Summary of the Invention

[0007] The system presented herein addresses the deficiencies in prior art monitoring systems for railcars and train consists. The system consists of a hierarchical arrangement of components which provide a distributed data analysis capability that is capable of detecting operational anomalies at various levels of the hierarchy, and which provides for the flow of data, events and alerts to a central point.

[0008] At the lowest level of the hierarchy, each railcar is equipped with multiple wireless sensor nodes (referred to in the singular as a "WSN"), which are arranged in a mesh network controlled by a communication management unit ("CMU"), usually on the same railcar, referred to herein as a railcar-based mesh network. The wireless sensor nodes collect data regarding various operational parameters of the railcar and are capable of detecting certain anomalies based on the collected data. When anomalous operational data is

detected, an alert may be raised and the data may be communicated to the communication management unit located on the railcar. Although mesh networks are used in the embodiments illustrated herein, other types of network topologies may be used.

[0009] The communication management units located on each railcar are also arranged in a mesh network which is controlled by a powered wireless gateway, typically located in the locomotive. This is referred to herein as a train-based mesh network. Again, although mesh networks are used in the embodiments illustrated herein, other types of network topologies may be used.

[0010] The train-based wireless mesh network communicates the length of the train consist and delivers information about the railcars to a powered host or control point, such as the locomotive or an asset with access to a power source and to a railroad remote operations center.

Brief Description of the Drawings

[0011] The present invention will be more fully and completely understood from a reading of the Detailed Description of the Invention in conjunction with the drawings, in which:

[0012] Figure 1 is a schematic of a railcar 103 equipped with a communication management unit (CMU) 101 and a plurality of wireless sensor nodes (WSNs) 104 installed thereon, forming a railcar-based mesh network 105.

[0013] Figure 2 is a schematic of a train-based mesh network with two railcars 103 each equipped with a CMU 101 and multiple WSNs 104, a railcar 103 equipped with just a CMU 101 (no WSNs), a railcar 103 without a CMU or WSN, and a powered wireless gateway device 102 installed on a locomotive 108.

[0014] Figure 3 shows a train-based mesh network 107 and various means of communicating data off-train.

[0015] Figure 4 is an exploded view of a first variety of WSN 104 which can be used, for example, for monitoring bearing temperature and wheel acceleration.

[0016] Figure 5 is an exploded view of a second variety of WSN 104 which can be used, for example, for monitoring railcar body acceleration, and which can include a temperature sensor (not shown) for monitoring temperature.

[0017] Figure 6 shows the WSN 104 of Figure 4 installed on a railcar wheel bearing fitting 111.

[0018] Figure 7 is a flow chart showing the conditions under which longitudinal impact acceleration event processing is enabled and disabled.

[0019] Figure 8 is a flow chart showing the conditions under which vertical and lateral hunting acceleration event processing is enabled and disabled.

[0020] Figure 9 is a flow chart showing the conditions under which derailment monitoring event processing is enable and disabled.

[0021] Figure 10 is a flow chart showing the conditions under which wheel damage or vertical impact event processing is enabled and disabled.

[0022] Figure 11 is a flow chart showing the conditions under which bearing temperature event processing is enabled and disabled.

[0023] Figure 12 is an architectural diagram showing a generalized model for implementation of the data analysis portion of a WSN 104.

[0024] Figure 13 is a specific implementation of the model shown in Figure 12 directed to detection of railcar body events.

[0025] Figure 14 is another specific implementation of the model shown in Figure 12, this one directed to detection of wheel bearing events.

Detailed Description of the Invention

[0026] A **railcar**, as the term is used herein, may be a single railcar 103, see Fig. 1, or may consist of two or more railcars 103 which are permanently connected, often referred to by those of skill in the art as a "tandem pair", "three-pack", "five-pack", etc.

[0027] A **train consist**, shown in the drawings as reference number 109, see Fig. 2, is defined as a connected group of railcars 103 and locomotives 108.

[0028] A **communication management unit** ("CMU"), shown in the drawings as reference number 101, is preferably located on a railcar 103 and controls the railcar-based mesh network 105 (defined below) overlaid on railcar 103 which may consist of one or more individual railcars 103 which are permanently connected together. The CMU 101 hardware preferably includes a processor, a power source (e.g. a battery, solar cell, energy harvester, or internal power-generating capability), a global navigation satellite system (GNSS) device such as a global positioning system ("GPS") receiver, Wi-Fi, satellite, and/or cellular capability, a wireless communications capability for maintaining the railcar-based mesh network 105, wireless communication with a train-based mesh network 107 and, optionally, one or more sensors, including, but not limited to, an accelerometer 404, gyroscope, or temperature sensor 406.

[0029] The CMU 101 supports one or more WSNs 104 (defined below) in a mesh network configuration using open standard protocols, such as the IEEE 2.4 GHz 802.15.4 radio standard. Additionally, the CMU 101 is also a member of a train-based mesh network 107, which consists of the CMUs 101 from all enabled railcars 103 in the train consist 109, controlled by a powered wireless gateway 102, typically located on a locomotive 108. The CMU 101 thus supports four functions: 1) to manage a low-power railcar-based mesh network 105 overlaid on a railcar 103; 2) to consolidate data from one or more WSNs 104 in the railcar-based mesh network 105 and to apply logic to the data gathered to generate warning alerts to a host such as a locomotive 108 or remote railroad operations center 120; 3) to support built-in sensors, such as an accelerometer 404, within the CMU 101 to monitor specific attributes of the railcar 103 such as location, speed, and accelerations, and to provide an analysis of this data to generate alerts; and 4) to support bi-directional

communication upstream to the host or control point, such as a locomotive 108 and/or an off-train monitoring and remote railroad operations center 120, and downstream to one or more WSNs 104, located on the railcar 103. CMUs 101 may communicate wirelessly to a powered wireless gateway (PWG 102 as defined below) in a mesh network configuration, or may be configured to communicate through a wired connection, for example, through the ECP (electronically controlled pneumatic) brake system. Those skilled in the art will appreciate that GPS is just one form of a global navigation satellite system (GNSS). Other types of GNSS include GLONASS and BeiDou with others in development. Accordingly, although GPS is used in the embodiments described herein, any type of GNSS system or devices may be used.

[0030] The CMU 101 is capable of receiving data and/or alarms from one or more WSNs 104 and is capable drawing inferences from this data or alarms regarding the performance of railcar 103, and of transmitting data and alarm information to a remote receiver. The CMU 101 is preferably a single unit that would serve as a communications link to other locations, such as a powered wireless gateway 102 (preferably located in locomotive 108), or a remote railroad operations center 120, and have the capability of processing the data received. The CMU 101 also communicates with, controls and monitors WSNs 104 in the local railcar-based mesh network 105.

[0031] A **powered wireless gateway** ("PWG"), shown in the drawings as reference number 102 (see, e.g., Fig. 2), is preferably located on a locomotive 108 or elsewhere on a train consist 109 where there is a source of external power. It typically will include a processor; a GPS receiver; one or more sensors, including, but not limited to, an accelerometer 404, gyroscope, or temperature sensor 406; a satellite and or cellular communication system; local wireless transceiver (e.g. WiFi); an Ethernet port; a high capacity mesh network manager and other means of communication. The PWG 102 will have power supplied by the locomotive 108, if located on a powered asset, such as a locomotive 108, or will derive its power from another source, for example, from a solar power generator or from a high-capacity battery. The PWG 102 controls

a train-based mesh network 107 overlaid on a train consist 109, consisting of multiple CMUs 101 from each railcar 103 in a train consist 109.

[0032] The components and configuration of the PWG 102 are similar to that of a CMU 101, with the exception that the PWG 102 typically draws power from an external source, while the CMU 101 is self-powered. Additionally, the PWG 102 collects data and draws inferences regarding the performance of the train consist 109, and train-based mesh network 107, as opposed to CMUs 101, which draw inferences regarding the performance of individual railcars 103 and railcar-based mesh network 105 or 118.

[0033] A **railcar-based mesh network** shown in the drawings as reference number 105, see, e.g., Figs. 1 and 2, consists of a CMU 101 on a railcar 103, which is part of and manages a railcar-based mesh network 105 of a plurality of WSNs 104, each deployed, preferably on the same railcar 103.

[0034] A **wireless sensor node** ("WSN"), shown in the drawings as reference number 104, see, e.g., Figs. 1 and 2, is located on a railcar 103, and provides the functions of collecting data from internal sensors and analyzing the data collected from the sensors to determine if the data needs to be transmitted immediately, held for later transmission, or aggregated into an event or alert. The WSN 104 is used for sensing a parameter to be monitored (e.g. temperature of bearings or ambient air) or status (e.g., position of a hatch or hand brake). In a preferred embodiment, each WSN 104 is equipped with one or more accelerometers or gyroscopes and one or more temperature sensors. Examples of WSNs 104 are disclosed in published U.S. patent application 2013/0342362, the disclosure of which is hereby incorporated by reference herein. A typical WSN 104 is shown in exploded view in Figure 4 and Figure 5 and will now be explained in more detail.

[0035] With reference to Figure 4, an example of a first variety of WSN 104 is now described. The WSN 104 shown in Figure 4 is configured and tuned to detect certain kinds of acceleration and temperature events and is typically located on the wheel bearing fitting 111 of railcar 103, where it is likely to be subjected to various degrees of accelerations and where it can easily collect data regarding the temperature of the wheel bearing. The components of WSN 104 are contained in a housing 400 having an enclosure 400a and an

enclosure base 400b. Preferably, housing sections 400a, 400b are composed of a hard plastic resistant to environmental damage, such as a UV rated polymer, e.g., a polycarbonate/ABS blend, and when fully assembled is weatherproof. After the various components are installed within the housing as described below, a potting material (not shown) is provided through openings in the housing 400 to isolate, encapsulate and environmentally seal the components within. Such materials include epoxies, polyurethanes and silicone compounds. A flexible urethane suitable for electrical use and through which wireless signals can be transmitted is preferred. It has been found that the particular potting material used is also critical in the proper tuning of the WSN 104 to detect various types of accelerations. A potting material having a durometer of 59 Shore 00 is preferred.

[0036] Additionally, a mechanical filter 410 consisting of upper sections 410a and lower sections 410b further serve to mechanically filter high and low frequency types of accelerations that are considered noise and which are preferably removed from the signal of interest. Preferably, these components are composed respectively of silicone of durometer 70 Shore A (the upper filter sections 410a) and 30 Shore A (the lower filter sections 410b) in view of the differences of the surface areas of each section and this affect on the filtering characteristics.

[0037] In a preferred embodiment, each WSN 104 may have one or more accelerometers 404 and one or more temperature sensors 406. The tuning of WSN 104 is accomplished by a combination of the selection of the potting material, the durometer of upper and lower silicone mechanical filtering elements 410a and 410 b, and software filtering performed by software executing on a processor on main PC board 402a. The software filter used is a digital filter to decrease noise from unwanted acceleration frequencies and increase signals from acceleration frequencies of interest.

[0038] Temperature sensor 406, includes a heat transfer element which extends through an opening 406a in the enclosure base 400b, and opening 406b in the

filter section 410b. Preferably, the heat transfer element is a copper plug. This configuration is preferred for monitoring the surface temperature of the surface to which WSN 104 is attached, as the heat transfer element will make contact with the surface. In preferred embodiments of the invention, the temperature sensor 406 is a thermistor, thermocouple or silicone temperature sensor which are ideal for electronic circuits. In this embodiment, WSN 104 will be mounted to place the heat transfer element in thermal communication with the portion of the railcar 103 for which a temperature reading is desired. Additionally, the lower sections 410b of the mechanical filter are of a suitable thickness to create an air gap between the enclosure base 400b and the surface to which the WSN 104 is mounted. The lower sections 410b of the mechanical filter and the air gap create good thermal protection and low heat transfer from the surface to which the WSN 104 is mounted. This thermal protection keeps the electronics (all except for the temperature sensor 406) and the power source from being exposed to excess and potentially damaging heat. WSN 104 may also be equipped with additional temperature sensors (not shown) for sensing the ambient temperature.

[0039] In the preferred embodiment, self-taping screws 415 serve to attach WSN 104 to the railcar 103 and to hold upper and lower portion 410a and 410b of mechanical filter in place. Spacers 400c which fit within the screw openings 410c of the filter pads are chosen in length to control the amount of compression force on the filter sections 410a and 410b due to the tightening of the screws 415. Without the spacers 400c, the filtering characteristics of the filters could be changed due to compression from over tightening of the screws 415. The spacers are chosen from a suitably stiff material.

[0040] As one of ordinary skill would recognize, the configuration of WSNs 104 may vary with respect to the number and types of sensors. Virtually any type of sensor could be used, including, for example, a temperature sensor 406, a pressure sensor, a load cell, a strain gauge, a hall effect sensor, a vibration sensor, an accelerometer 404, a gyroscope, a displacement sensor, an

inductive sensor, a piezio resistive microphone or an ultrasonic sensor, depending on the specific operational parameter that is desired to be monitored. In addition, the sensor may be a type of switch, including, for example, reed switches and limit switches. An example of another type of mote sensor which uses a strain gauge, e.g. a hand brake monitor sensor, is described in U.S. patent publication 2012/0046811 (US Patent Application 12/861,713 filed August 23, 2010), the disclosure of which is hereby incorporated herein by reference.

[0041] Electrical circuitry is provided for the operation of WSN 104. The electrical circuitry includes the components and wiring to operate and/or receive and process the signals from the sensors. This can include, but is not limited to, analog and digital circuitry, CPUs, processors, circuit boards, memory, firmware, controllers, and other electrical items, as required to operate the accelerometers and temperature sensors 406 and to process the information as further described below.

[0042] In the illustrated embodiment in Figure 4, the circuitry includes a main board 402a which includes the communications circuitry, antennae and microprocessor and a daughter board 402b which includes circuitry to read the data from accelerometers 404 and temperature sensors 406. Main board 402a, daughter board 402b or the sensors may also include a processor executing firmware to provide intelligence sufficient to perform low-level analysis of the data, and may accept parameters from outside sources regarding when alarms should be raised, as described below.

[0043] Each WSN 104 also includes circuitry for wireless communications and a long-term power source 414(e.g. a battery, solar cell, energy harvester, or internal power-generating capability), preferably a military grade lithium-thionyl chloride battery. The circuitry also provides power conditioning and management functions and may include a feature to conserve battery life which keeps WSN 104 in a standby state and periodically wakes WSN 104 to deliver readings from the sensors.

[0044] Figure 5 shows an exploded view of a second variety of WSN 104, which is preferably mounted on the body of railcar 103. The variety of WSN 104 shown in Figure 5 is substantially identical to the variety shown in Figure 4 (and thus similar elements are identified with the same reference number), with the following differences. First, as this variety of WSN 104 will be mounted to the body of railcar 103, where it is likely to be subjected to more gentle accelerations, there is no need for the additional mechanical filtering provided by mechanical filters 410 of Figure 4. Thus, using four screws, two on each side, and given that this WSN is not exposed to the more violent accelerations of the other variety, the screws or bolts of this second variety can be smaller in diameter. Second, the illustrated embodiment does not include a temperature sensor 406, although one or more temperature sensors 406 may be provided with a heat transfer element, as discussed above for the first variety, extending through an opening in the housing to sense the desired temperature, e.g., the ambient temperature. Lastly, although this variety of WSN 104 includes an accelerometer 404 like the prior described WSN 104 of Fig. 4, it preferably will be programmed with different firmware to detect different types of acceleration events, as discussed below. As understood by one of ordinary skill, the WSNs of both varieties could also contain just a temperature sensor, although there would be no need for filtering as described with reference to Fig. 4.

[0045] Individual WSNs 104 are mounted on the areas of interest on a railcar 103. As an example, Figure 6 shows WSN 104 of the type shown in Fig. 4 mounted to a roller bearing fitting 111 of a railcar wheel bearing of a railcar 103. The unit may be attached using a thermally conductive epoxy adhesive between the heat transfer element and the roller bearing fitting 111 to ensure good heat transfer to the temperature sensor 406, and mechanical fasteners such as self-tapping screws 415 to hold WSN 104 in place.

System Operation

[0046] In broad terms, with reference to Figs. 1 and 2, the present invention provides a novel means for monitoring the performance and operation of a railcar 103 and train consist 109. This includes a plurality of sensors 104 deployed on the railcars 103 in the consist 109 for sensing various operational parameters of the railcar 103 and distributed complex event processing (DCEP) engine, which is a hierarchical system for collecting and analyzing the data and for communicating data, events and alerts to a final destination where they can be acted upon.

[0047] The DCEP is responsible for implementing the intelligence used to draw conclusions based on the data collected from WSNs 104, CMUs 101 and PWGs 102. Preferably, the data processing platform is distributed among all WSNs 104, CMUs 101 and the PWG 102 on the locomotive 108, as well as utilizing a cloud-based infrastructure optimized to work closely with train-based mesh networks 107, in conjunction with a variety of data streams from third-party providers or external sources.

[0048] With further reference to Fig. 1 of the drawings, a railcar-based mesh network is shown generally as reference number 105. Railcar-based mesh network 105 comprises a CMU 101 installed on a railcar 103 and one or more WSNs 104 installed on the same railcar 103. Railcar 103 may consist of one or more individual railcars 103, which are permanently connected together. The railcar-based mesh network 105 is a critical component in the processing of events and alerts on the railcar 103. CMU 101 and WSNs 104 work together to collect and analyze the data collected from sensors in the WSNs 104. CMU 101 controls the railcar-based mesh network 105 on railcars 103 and is able to configure one or a more WSNs 104 in a local mesh network to transmit, listen, or sleep at precise times, or to change the parameters under which WSNs 104 operate and detect events.

[0049] With further reference to Figure 2, a schematic of a train-based mesh network 107 is shown with two railcars 103 each equipped with a CMU 101 and multiple WSNs 104 installed near the wheel bearings of the railcar 103, a railcar 103 equipped with just a CMU 101 with no WSNs 104 attached, a railcar 103 without a CMU 101, and a PWG 102 installed on a locomotive 108. The CMU 101 and multiple WSNs 104 installed on railcars 103 form a

railcar-based mesh network 105 and communicate with the PWG 102 on a host or control point, such as a locomotive 108 or other asset, forming the train-based mesh network 107. The railcar-based mesh network for the railcar 103 having a CMU 101 only and no WSNs is designated 118.

[0050] If an alert or event condition is detected by a WSN 104, as described in more detail below, a message is forwarded by WSN 104 to CMU 101 for further analysis and action, for example, to confirm or coordinate alert or event conditions reported by one WSN 104 with other WSNs 104 in the railcar-based mesh network 105. If an alert or event is confirmed by CMU 101, a message is sent to PWG 102 installed on an asset, preferably with access to a power source and/or to an off train monitoring and remote railroad operations center 120.

[0051] CMU 101 on each railcar 103 is capable of supporting an optional global navigation satellite system (GNSS) sensor to determine location, direction and/or speed of railcar 103. This information can be used to determine whether or not WSNs 104 should be looking for certain types of events. For example, it is fruitless for a WSN 104 to attempt to detect derailments when the train consist 109 is stationary. Additionally, the PWG 102 can send instructions for the CMU 101 to start or stop looking for certain types of events. Additionally, CMU 101 on each railcar 103 is capable of using built-in sensors and/or managing a railcar-based mesh network 105 on the railcar 103 to generate messages that need to be sent to a host or control point, such as a locomotive 108.

Alert and Event Detection and Reporting

[0052] Each WSN 104 is capable of analyzing the data collected from its sensors in determining if the an event or alert message, as well as the data should be uploaded to the next higher level in the hierarchy, in this case CMU 101. With respect to accelerometers 404, each WSN 104 can be programmed with

multiple thresholds for peak and root mean square (RMS) level of magnitude values acceleration readings received from the one or more accelerometers 404. When one of the peak or RMS acceleration thresholds are exceeded, it is an indication of a possible event or alert condition, and a message is generated and sent to CMU 101 in the same railcar-based mesh network 105. The thresholds for each variety of WSN 104 may be dynamically programmed by commands either generated internally or received externally from CMU 101.

[0053] In the preferred embodiment, WSNs 104 are programmed with thresholds which indicate specific types of alerts or events. For the WSNs 104 mounted on wheel roller bearing fittings 111, these units may generate a possible derailment message, a vertical impact message or a wheel damage message depending upon the threshold which is exceeded. For WSNs 104 located on the body of railcar 103, examples of messages generated are longitudinal impact, extreme lateral railcar dynamics, extreme vertical railcar dynamics, vertical hunting and lateral hunting. In the illustrated embodiments, the WSNs 104 do not determine if each of the possible conditions actually exists. This determination is preferably made at the next level up of the hierarchy, at CMU 101, which utilizes the readings from multiple WSN 104 to make a determination that an actual event has occurred. As would be readily realized by one of skill in the art, different thresholds suggesting the occurrence of other types of events may be programmed into WSNs 104.

[0054] Regarding the temperature sensors 406 in each WSN 104, which are capable of sensing the temperature of the surface on which a WSN 104 is installed and/or the temperature of ambient air around the WSN 104, the temperature readings from each WSN are periodically reported to the CMU 101. The CMU 101 must coordinate the collecting of temperature data from all WSNs 104 in the railcar-based mesh network 105 and, as such, the period for reporting of temperatures, as well as the timing of the reporting of temperature data is programmed for each WSN 104 by CMU 101.

[0055] Each WSN 104 is able to make a determination of when to report data that may indicate a possible event or alarm condition to CMU 101. CMU 101 is able to collect such notifications from each WSN 104 under its control and coordinate the data to make a final determination as to whether or not an event or alarm condition actually exists. For example, in the preferred embodiment each wheel roller bearing fitting 111 in a railcar 103 will have a WSN 104 attached thereto to monitor accelerations and temperature. Thus, on a typical railcar 103 having two trucks (bogies), each with two axles, a total of eight WSNs 104 mounted to wheel roller bearing fitting 111 will be present. In addition, and also in accordance with a preferred embodiment, each railcar 103 will preferably have an additional WSN 104 located at each end of the railcar 103 attached directly to the railcar body. CMU 101 also may include acceleration, temperature or any other type of sensors and may replace one or more of the WSN 104s on the body of railcar 103 or may be supplemental to the set of WSN 104s that are installed on the body of railcar 103. The railcar-based mesh network 105 may include any combination of WSNs 104, including a configuration wherein the CMU 101 is the only component installed on the railcar 103. Additionally, CMU 101 may also monitor WSNs 104 installed on other railcars 103 such as in the case where railcar 103 may consist of one or more individual railcars 103 which are permanently connected together.

[0056] In the preferred embodiment, the logic in the CMU 101 is capable of analyzing both acceleration and temperature events received from each of the WSNs 104 under its control and determining if an alarm or event condition actually exists. It should be noted that acceleration events are independent of temperature events and the CMU 101 may be configured to either analyze only acceleration events, or to analyze only temperature events. Thus the CMU 101, and WSNs 104 under its control, form a distributed event processing engine which is capable of determining various types of events.

[0057] The acceleration events which CMU 101 is capable of detecting in the preferred embodiment will now be discussed in greater detail. It should be noted that when CMU 101 determines that an alarm or event has occurred, a message is sent to the next level in the hierarchy that is either to a PWG 102 located elsewhere on train consist 109 or off train consist 109 to a remote railroad operation center 120, depending upon the severity of the event and the need to immediately address the event, perhaps by altering the train consist's 109 operating condition. Examples of events that can be analyzed using the features described above are provided below.

[0058] Derailment – A derailment event is regarded as a high priority type of event and is an example of the type of events that can be analyzed by the illustrated embodiment. When a derail message is received from a WSN 104, the CMU 101 starts a derailment processing timer and also immediately generates a possible derailment message to the PWG 102. CMU 101 then waits to determine if any other WSNs 104 are generating derailment messages. If other WSNs 104 have generated derailment messages within a predetermined time interval, they are all presumed to have originated from the same physical event and a derailment message is generated and sent to PWG 102.

[0059] Figure 9 is a flow chart showing the conditions under which the derailment event is enabled or disabled. At 900, the system is initialized and, at 902, the system is placed in a waiting state in anticipation of the railcar 103 moving, wherein the derail event is disabled. It should be noted that derailment events are disabled when the railcar 103 is stationary. At 904, the system checks to see if the railcar 103 is stationary and, if it is, it returns to the waiting state at 902. If the railcar 103 is moving control moves to 906 where the derailment event is enabled. The derailment event is enabled by having CMU 101 send a message to each of the WSNs 104 under its control. At 908, the system is again placed in a waiting state; however, the derailment event is now enabled. At 910, the system queries as to whether a derailment has been detected and, if not, control proceeds to 914 where the system queries as to

whether the railcar 103 is stationary. If the railcar 103 is moving, control returns to 908, the system waiting state, having the derailment event enabled. If at 910 a derailment is detected, control proceeds to 912 where a system report of a derailment is made and control then proceeds to 914 as before. If, at 914, it is determined that the railcar 103 is again stationary, the derailment event is disabled at 916 and control returns to 902, where the system waits in a state where the derailment event is disabled.

[0060] Vertical Impact – A vertical impact message is regarded as a medium priority type of event. When a vertical impact event is received from a WSN 104, CMU 101 starts a vertical impact processing timer during which CMU 101 waits to see if any other vertical impact events are received from other WSN 104s. Depending on which side of the railcar 103 vertical impact messages are being generated, it can be determined, for example, that a broken rail or other track condition may exist.

[0061] Wheel Damage – A wheel damage message is regarded as a low priority type of event. When a wheel damage event is received from a WSN 104, CMU 101 starts to listen for additional wheel damage events from the same WSN 104. Thus, if CMU 101 receives multiple wheel damage messages from the same WSN 104, it can generate a wheel damage message. In such cases, CMU 101 may instruct WSN 104 to stop looking for wheel damage events as these will likely continue to recur and generate a barrage of messages from WSN 104 to CMU 101. In addition, the WSN 104 will have a counter to determine if it is sending wheel damage messages to the CMU 101 at a certain rate. If that rate is exceeded, the WSN 104 stops checking for wheel damage messages for a certain time period. After the time period has expired, the WSN 104 will check to see if the rate of wheel damage messages are still too high to send to the CMU 101.

[0062] Figure 10 is a flow chart showing the conditions under which the wheel damage and vertical impact events are enabled or disabled. At 1002, the system is initialized and, at 1004, the system is placed in a waiting state

wherein the events are disabled, as the critical speed required for event enablement has not yet been reached. Wheel damage and vertical impact events are only enabled when railcar 103 has reached a specific critical speed. Note that the speed of railcar 103 can be determined by several means, one preferred way is for a message to be sent from PWG 102 to all CMUs 101 in train consist 109. At 1006, the system checks to see if the critical speed has been reached or exceeded. The critical speed is a configurable setting of the system, typically set by each individual user, based on track and operational conditions, and is used to identify that the train is moving at a speed when such data is relevant. If not, control returns to 1004 where the system is again placed in a waiting state with the events disabled. If, at 1006, the critical speed has been reached or exceeded, control proceeds to 1008 where both the vertical impact and wheel damage events are enabled. Control then proceeds to 1010, where the system is placed in a waiting state having both types of events enabled. At 1012, if a vertical impact event has been detected, control proceeds to 1014 where the system reports the vertical impact. At 1016, the system checks to see if a wheel damage event has been detected and, if so, reports the wheel damage at 1018. In any event, control then proceeds to 1020, where the system checks to see if the railcar 103 is still at the critical speed necessary for the enablement of events. If it is, the system proceeds back to 1010 where the system is placed in a waiting state with events enabled. If the speed of railcar 103 has fallen below the critical speed, control proceeds to 1022 where both the vertical impact and wheel damage events are disabled, and then to 1004 where the system is placed in a waiting state with events disabled.

[0063] The proceeding acceleration events are all events which are detected by the variety of WSN 104 which is attached to the wheel roller bearing fitting 111 on railcar 103. The following events are all generated by the variety of WSN 104 which is attached to the body of railcar 103.

[0064] Longitudinal Impact – A longitudinal impact occurs when an acceleration is detected along the length of railcar 103, and is regarded as a medium priority type of event. When a longitudinal impact message is received from a WSN 104, the CMU 101 starts a timer during which it looks for other longitudinal impact events from other WSNs 104. Longitudinal impact events are likely to occur, for example, during the coupling process and when the train consist 109 starts and stops. CMU 101 may coordinate with other CMUs 101 on other railcars 103 to determine if longitudinal impact events which are generated on each railcar 103 originate from the same physical event.

[0065] Figure 7 is a flow chart showing the conditions under which longitudinal events are enabled. At 700, the system is initialized and at 702 the longitudinal events are enabled. The control then proceeds to 704 where the system is placed in a wait state with the events enabled and enters a detection loop. At 706 the system determines whether a longitudinal impact has been occurred and, if not, returns to 704 where the system again enters the wait state. At 706, if a longitudinal impact has been detected, control transfers to 708 where the system generates and reports a message regarding the impact. Control then returns to 704 where the system again enters the wait state.

[0066] Vertical Extreme Vehicle Dynamics – A vertical extreme vehicle dynamics event occurs when an acceleration is detected in the vertical direction of railcar 103, and is regarded as a medium priority type of event. An event is detected by a peak acceleration threshold being exceeded by an acceleration along the vertical axis. When a vertical extreme vehicle dynamics message is received from a WSN 104, the CMU 101 starts a timer during which it looks for other vertical extreme vehicle dynamics events from other WSNs 104. Vertical extreme vehicle dynamics events are likely to occur, for example, from a subsidence in the track or change in track modulus at a bridge abutment. CMU 101 may coordinate with other CMUs 101 on other railcars 103 to determine if vertical extreme vehicle dynamics events which are generated on each railcar 103 originate from the same physical event.

[0067] Lateral Extreme Vehicle Dynamics– A lateral extreme vehicle dynamics event occurs when an acceleration is detected in the lateral, or cross line, direction of railcar 103, and is regarded as a medium priority type of event. An event is detected by a peak acceleration threshold being exceeded by an acceleration along the lateral axis. When a lateral extreme vehicle dynamics message is received from a WSN 104, the CMU 101 starts a timer during which it looks for other lateral extreme vehicle dynamics events from other WSNs 104. Lateral extreme vehicle dynamics events are likely to occur, for example, from a subsidence in the track or change in track modulus at a bridge abutment. CMU 101 may coordinate with other CMUs 101 on other railcars 103 to determine if lateral extreme vehicle dynamics events which are generated on each railcar 103 originate from the same physical event.

[0068] Vertical Hunting – Vertical hunting is a condition that can last a long time with certain dynamic conditions such as track corrugation. The WSN 104s located on each end of the railcar 103 body are commanded to periodically check for vertical hunting simultaneously, which allows a phase comparison of the readings from each WSN 104. When CMU 101 receives a vertical hunting message, a vertical hunting processing timer is started and CMU 101 waits to see if another WSN 104 has reported a vertical hunting event during a predetermined time interval. If multiple events are received within the time interval, CMU 101 examines the messages received and if the data indicates similar periodic oscillations at each end of the railcar 103, then the phase relationship between events occurring at each end of the railcar 103 is determined. For an in phase oscillation, the CMU 101 generates a railcar "body bounce" event. When the data indicates out of phase oscillation, CMU 101 generates a railcar "body pitch" event. In both cases the vertical hunting message is reported by CMU 101.

[0069] Lateral Hunting – Lateral hunting is a condition that can last a long time with certain dynamic conditions. Factors that contribute to lateral hunting include: high center of gravity railcars 103, worn trucks (bogies), and worn tangent

track. The lateral hunting event detection works in a fashion similar to the detection of the vertical hunting events. When CMU 101 receives a lateral hunting event from one of the WSNs 104s on one end of the railcar 103 (e.g., the front end), a timer is started and, if another event is received from another WSN 104 on the other end of the same railcar (e.g., the back end) within a predetermined period of time then the events are compared for their phase relationship. If the data indicates an out of phase oscillation, then a "body yaw" event is generated. However, if the data indicates an in phase oscillation a "body roll" event is generated. In either case, a lateral hunting message is reported by CMU 101.

[0070] Figure 8 is a flow chart showing the enabling, disabling, and reporting of vertical and lateral hunting events. At 800, the system is initialized and, at 802, the system is placed in a waiting state with the events disabled. Events, in this case, are disabled when the speed of railcar 103 is below a critical speed. Vertical and lateral hunting events are only enabled when the speed of railcar 103 exceeds the critical speed. At 804, the system checks to see whether critical speed has been exceeded and, if not, returns to the system waiting state in 802. However, if the critical speed has been exceeded, at 806, the vertical and lateral hunting events are enabled and, at 808, the system enters a loop wherein the hunting data is sent to CMU 101 and then analyzed to see if a hunting event has occurred. At 810, CMU 101 analyzes the data and, at 812, determines whether or not a hunting event has been detected. If a hunting event has been detected, control proceeds to 814 where the event is reported. If no hunting event has been detected in 812, control proceeds directly to 816 where the system again checks to see if the speed of railcar 103 is over the critical speed. If the speed of railcar 103 is still high enough for hunting events to be enabled, control returns to 808 and the system again enters the loop. If the speed of railcar 103 has fallen below the critical speed, control proceeds to 818, where the hunting events are disabled, and then to 802, where the system is placed in the waiting state with events disabled.

[0071] With reference to Figs. 4 and 12, a general implementation model of the analysis system of a WSN 104 is now described. As depicted in the preferred embodiment, the analyzed signal (what is not filtered out by the mechanical filter 410 or potting material), originates with accelerometer hardware 404 and is passed to one or more sensor sections 1202, 1208 or 1214. These sensor sections select the data to be analyzed using a digital data filter 1204, 1210 or 1216, and passes this data on to a feature detector 1206, 1212 or 1218. Data selection can be based on, for example, direction (e.g. vertical or longitudinal components), frequency (e.g. high-frequency clangs or low frequency rocking), overall magnitude (combination of 2 or 3 directional components), or other variations of the collected data.

[0072] The feature detectors may use a variety of techniques to determine if specific features are present. Features may include but are not limited to, pulse peaks or duration, root mean square (RMS) level of magnitude values, or presence or lack of specific frequency components. Once a feature is detected, a message is passed on to message module 1220 to be delivered to the CMU 101. The sensor section may also perform periodic tests to determine if the feature is still present. If it is, the section can also determine if continued messages should be sent or if a message should be sent only when the feature is no longer present.

[0073] One possible implementation of the analysis system of Fig. 12 is shown in Figure 13. Here, accelerometer 404 passes data on to three sensor sections. The first section 1302 selects data from the longitudinal direction down the length of the railcar 103 and uses Longitudinal Section 1304 to extract longitudinal impact data. Longitudinal impacts are detected in Impact Detector 1306 when the peak value of the longitudinal data exceeds a longitudinal impact threshold. The second section 1308 selects data from the lateral direction across the railcar 103 and uses Lateral Section 1310 to extract lateral oscillation data. Lateral oscillations are detected in Vehicle Dynamics Detector 1312 when the RMS value of the oscillations exceeds a lateral oscillation threshold. The third section 1314 selects data from the vertical direction and uses Vertical Section 1316 to extract vertical oscillation data. Vertical oscillations are detected in Vehicle Dynamics Detector 1318 when the RMS value of

the oscillations exceeds a vertical oscillation threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

[0074] Another possible implementation of the analysis system is shown in Figure 14. Here, accelerometer 404 passes data on to three sensor sections. The first section 1402 looks at data from the vertical direction and uses Vertical Derailment Filter 1404 to extract the characteristic frequencies of a derailment. Derailment events are detected in Derailment RMS Detector 1406 when the RMS value of the filtered data exceeds a derailment threshold. The second section 1408 also selects data from the vertical direction, but uses Vertical Wheel Damage Filter 1410 to extract the characteristic frequencies of wheel damage. Wheel damage is detected in Wheel Damage RMS Detector 1412 when the RMS value of the filtered data exceeds a wheel damage threshold. The third section 1414 also selects data from the vertical direction and uses Vertical Impact Filter 1416 to extract vertical impact data. Vertical impacts are detected in Vertical Impact Peak Detector 1418 when the peak value of the filtered data exceeds a vertical impact threshold. Each of these sensor sections sends its messages on to message module 1220 which, in turn, passes these messages on to the CMU 101.

[0075] When a derailment occurs, the wheels of one or more axles fall off the rails and run along the track bed. The rough nature of the track bed causes the derailed wheels to experience high-energy vertical accelerations for the duration of the derailment. In a preferred embodiment, a derailment is readily identified by calculating the RMS value of a series of consecutive vertical acceleration measurements and comparing the result with a threshold. If the CMU sees such data from the WSNs on both sides of the same axle, this could indicate a derailment. On the other hand, acceleration data from a single WSN regarding just one wheel processed through sensor section 1408 is more likely to indicate a damaged wheel.

[0076] CMU 101 also collects temperature data from each WSN 104. The collection of temperature data from each WSN 104 must be synchronized to avoid conflicts between WSNs 104 while transmitting the data to CMU 101,

and to allow timely comparison and coordination of the temperature data from the readings from WSNs 104. This is achieved by storing the temperature data in a rotating buffer organized as one data set comprising one reading from each WSN 104 temperature sensor 406. In the preferred embodiment, each WSN 104 samples its temperature sensors 406 once per minute, four consecutive samples are averaged once every 4 minutes. The WSN 104 then sends a message containing 8 consecutive sample averages to the CMU 101 once every 32 minutes. CMU 101 keeps twenty samples in its rotating buffer for each temperature sensor 406, however, one of skill in the art would realize that other sampling intervals and buffer sizes could be used. It should be noted that WSNs 104 may have more than one temperature sensor 406. After each temperature message is received, the oldest set of data in the rotating buffer is discarded. When the data set is complete, the temperature data is examined for any significant temperature trends or events and then cleared so that the temperature data is used only once. As newer temperature messages are received, the buffer wraps around so that new data overwrites the oldest time slots. It should be noted that the WSNs 104 do not analyze the temperature data for specific events, but instead merely report it to the CMU 101. The CMU 101 examines the temperature data for trends and reports when certain thresholds have been detected. It should be noted that the temperature analysis is only performed when the train consist 109 is moving and is disabled when the train consist 109 is stationary. Therefore, WSNs 104 will not collect or report temperature data unless the train consist 109 is moving.

[0077] The following table is a listing of the alarms and warnings generated by the statistical analysis performed by the CMU 101 on the temperature data.

Peak Analysis	Greater than x% of the temperature readings in the analysis statistics exceed the absolute temperature analysis threshold

Ambient Analysis	Greater than y% of temperature readings in the analysis statistics exceed the above ambient temperature analysis threshold
Rate Analysis	z% of the operational time exhibits a temperature rise exceeding the temperature rate analysis threshold

The variables x, y and z, in the above table indicate that these numbers are configurable depending on the preferences of the user or customer. As an example of a Peak Analysis operation, if x (as configured by the user, e.g., 20, 25 or 30) percentage of temperature readings on a bearing over a period of time exceed the absolute temperature analysis threshold, an alarm or warning may be sent. As an example of the usefulness of carrying out the different analyses, it is possible that the Ambient Analysis on a hot bearing, if the train is running in very hot weather conditions, might not indicate a problem when in fact there might be one, while the Peak Analysis which looks just at the bearing temperature will provide a warning or alarm. On the other hand, in very cold weather, the Peak Analysis may not indicate a problem with a hot bearing due to the cold weather cooling down the bearing, while the Ambient Analysis would. An example of Rate Analysis – when the railcar is not moving, a bad bearing will be at ambient temperature, but once the railcar starts moving, the bad bearing may heat up quicker than the other bearings on the railcar, and therefore will have a higher percentage of operational time it exceeds the threshold temperature rate.

[0078] As with acceleration events, WSNs 104 are also able to check for temperature events and report when the measured temperature exceeds certain thresholds. The table below lists these temperature-related alarms and events that can be provided immediately:

Peak Alarm	Absolute temperature alarm threshold is exceeded
Peak Warning	Absolute temperature warning threshold is exceeded
Ambient Alarm	Temperature above ambient alarm threshold is exceeded
Ambient Warning	Temperature above ambient warning threshold is exceeded
Differential Alarm	Temperature difference alarm threshold is exceeded between bearings on the same axle

The first four Alarms and Warnings in the above table are based on data preferably collected by individual WSNs and do not require any analysis other than the exceeding of a threshold and thus can be initiated by the WSN that collected the data. The last one, the Differential Alarm, requires data from at least two WSNs located on bearing fittings on opposite sides of an axle, and therefore the analysis and Alarm will preferably be carried out by the CMU.

[0079] Figure 11 is a flow chart showing the processing of events related to the measurement of temperatures of the wheel bearings of railcar 103. At 1100, the system is initialized and, at 1102, the system enters a waiting state wherein the temperature monitoring events are disabled. Events are disabled, in this case, when the railcar 103 is not moving. At 1104, the system checks to see if the railcar is moving and, if not, returns to 1002 where it again enters the waiting state with events disabled. If the railcar is moving, control proceeds to 1106 where the temperature monitoring events are enabled. The system then proceeds to 1108 where it enters a loop wherein events are checked. Control proceeds to 1110 where the system again checks to see

make sure the railcar 103 is moving. If the railcar 103 is not moving, control proceeds to 1112 where the temperature monitoring events are disabled and then back to 1102 where the system is placed in a waiting state with events disabled. If, at 1110, the railcar 103 is still moving, control proceeds to 1114 where the system checks to see if a set of temperature measurements are available. If not, control returns to 1108 where the system is in the waiting state with events enabled. If a set of temperature measurements is available in 1114, control proceeds to 1116 wherein the WSN 104 transmits the set of temperature measurements to CMU 101. At 1118, CMU 101 performs an analysis of the temperature measurements, including all those in the rotating buffer and, in at 1120, decides if a temperature threshold has been exceeded. If not, control returns to 1108 where the system is in a waiting state with events enabled. If a temperature threshold has been exceeded, the system reports the temperature measurements at 1122 and then returns to 1108 where it is again in the system waiting state with events enabled.

[0080] CMU 101 also detects long term trends and keeps data regarding trends in the analysis of bearing condition. The following statistics are collected for every bearing being monitored by a WSN 104 in the railcar-based mesh network 105:

1. Total number of valid temperature readings;
2. Sum of valid temperature readings;
3. Sum of valid temperature readings squared;
4. Number of temperature readings greater than the absolute temperature threshold;
5. Number of temperature readings greater than the above ambient temperature threshold; and
6. Number of temperature change rates greater than the heating rate threshold.

[0081] The bearing temperature statistics are accumulated on a daily basis in a rotating buffer that can hold thirty-two sets of data, thus allowing trend analysis over a thirty-day period. The DCEP engine controls the time that statistics are accumulated as a new set of statistics has begun and the oldest is discarded. Normally the event engine is configured to generate an analysis once per day.

[0082] The collected statistics may be used to calculate information that indicates bearing wear trends. In a preferred embodiment, a CMU 101 provides a report upon request of the following quantities for every wheel bearing:

a. Average bearing temperature;

b. Variance of bearing temperature;

c. Percentage of bearing temperature readings that exceed an absolute threshold;

d. Percentage of bearing temperature readings above ambient that exceed a threshold; and

e. Percentage of measurements that the rate of increase of bearing temperature exceeds a threshold.

[0083] A **train-based mesh network** is shown generally as reference number 107 in Figs. 2 and 3. Train-based mesh network 107 is overlaid on a train consist 109 and includes a PWG 102 installed on a host or control point such as a locomotive 108, or on another asset with access to a power source, and one or more CMUs 101, each belonging to the train-based mesh network 107 and also to their respective railcar-based mesh networks 105, if one or more WSNs 104 are present, or respective railcar-based mesh networks or network 118 for railcars 103 with a CMU 101 but no WSNs 104 (see Fig. 2). (Note that there can also be railcars 103 in train consist 109 without a CMU 101 thereon, as shown by reference number 119 in Figure 2). Thus, here, CMUs 101 can belong to two mesh networks, railcar-based mesh network 105 (if railcar 103 is fitted with one or more WSNs 104) and train-based mesh

network 107. Each CMU 101 is also optionally managing its respective railcar-based mesh network 105. Fig. 3 shows a case wherein the train-based mesh network 107 consists of three CMUs 101, two of which are part of railcar-based mesh networks 105, and one located on a railcar 103 (reference number 118) wherein no WSNs 104 are connected.

[0084] Train-based mesh network 107 uses an overlay mesh network to support low-power bi-directional communication throughout train consist 109 and with PWG 102 installed on locomotive 108. The overlaid train-based mesh network 107 is composed of wireless transceivers embedded in the CMU 101 on each railcar 103. Each CMU 101 is capable of initiating a message on the train-based mesh network 107 or relaying a message from or to another CMU 101. The overlay train-based mesh network 107 is created independently of, and operates independently of the railcar-based mesh networks 105 created by each railcar 103 in the train consist 109.

[0085] A bi-directional PWG 102 manages the train-based mesh network 107 and communicates alerts from the CMUs 101 installed on individual railcars 103 to the host or control point, such as the locomotive 108, wherein the alerts or event reports may be acted upon via human intervention, or by an automated system. Locomotive 108 may include a user interface for receiving and displaying alert messages generated by train-based mesh network 107 or any of the individual railcar-based mesh networks 105. Bi-directional PWG 102 is capable of receiving multiple alerts or events from CMUs 101 on individual railcars 103 and can draw inferences about specific aspects of the performance of train consist 109.

[0086] Bi-directional PWG 102 is also capable of exchanging information with an external remote railroad operations center 120, data system or other train management system. This communication path is shown in Fig. 3 as reference number 122, and can include cellular, LAN, Wi-Fi, Bluetooth, satellite, or other means of communications. This link can be used to send alerts off-train consist 109 when the train consist 109 is in operation.

[0087] It is appreciated that described above are novel systems, devices and methods. It is also understood that the invention is not limited to the embodiments and illustrations described above, and includes the full scope provided by the claims appended hereto.

* * * * *

We claim:

1. A system for detecting operational anomalies on a train consist or railcar comprising:

a) one or more communication management units mounted on one or more railcars;

b) one or more sensors located on said one or more railcars for sensing an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units; and

c) wherein said communication management units perform the functions of:

i) collecting data regarding said one or more railcar operational parameters;

ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

iii) communicating a message to a remote receiver when said trend or event is detected.

2. The system of claim 1 further comprising one or more wireless sensor nodes in communication with one of said communication management units, said one or more sensors forming part of said one or more wireless sensor nodes.

3. The system of claim 2 wherein each of said wireless sensor nodes performs the functions of:

a) collecting data from one or more sensors;

b) comparing said data against one or more rules; and

c) sending a message to said communication management unit when at least one of said rules is satisfied.

4. The system of claim 2 wherein each of said wireless sensor nodes performs the functions of:

a) collecting data from one or more sensors; and

b) periodically sending said collected data to said communication management unit.

5. The system of claim 3 wherein said one or more rules are numerical thresholds which, when exceeded by said collected data, cause an alert message to be sent to said communication management unit.

6. The system of claim 5 wherein said data is acceleration data.

7. The system of claim 5 wherein said data is temperature data.

8. The system of claim 5 wherein said communication management unit, upon receiving an alert message from one of said wireless sensor nodes, performs the functions of:

a) waiting to see if similar messages are received from one or more other wireless sensor nodes within a predetermined period of time and concluding that an actual event has occurred if said similar messages are received; and

b) communicating a message reporting the occurrence of said actual event to a remote receiver.

9. The system of claim 4 wherein said communication management unit, upon receiving said periodically sent data, performs the functions of:

a) storing said data in a data store;

b) analyzing said stored data for trends; and

c) generating a report when trends of interest are detected.

10. The system of claim 8 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to see if acceleration thresholds representing one or more of the following have been exceeded: wheel damage, vertical impacts or derailment.

11. The system of claim 8 wherein said wireless sensor node is mounted on the body of a railcar and further wherein said data is analyzed to see if acceleration thresholds representing one or more of the following have been exceeded: vertical hunting,

lateral hunting, vertical extreme vehicle dynamics, lateral extreme vehicle dynamics, or longitudinal impacts.

12. The system of claim 7 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to see if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded.

13. The system of claim 8 wherein said communication management unit confirms that a derailment event has occurred when derail messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

14. The system of claim 8 wherein said communication management unit confirms that vertical hunting is occurring when vertical hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

15. The system of claim 14 wherein said communication management unit determines that a body bounce event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate in phase accelerations were detected.

16. The system of claim 14 wherein said communication management unit determines that a body pitch event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate out of phase accelerations were detected.

17. The system of claim 8 wherein said communication management unit confirms that a lateral extreme vehicle dynamic event has occurred when lateral extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

18. The system of claim 8 wherein said communication management unit confirms that a vertical extreme vehicle dynamic event has occurred when vertical extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

19. The system of claim 8 wherein said communication management unit confirms that lateral hunting is occurring when lateral hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

20. The system of claim 19 wherein said communication management unit determines that a body yaw event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate out of phase accelerations were detected.

21. The system of claim 19 wherein said communication management unit determines that a body roll event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate in phase accelerations were detected.

22. The system of claim 7 wherein said wireless sensor node is mounted on the wheel bearing fitting of a railcar and wherein said data is analyzed to determine if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded.

23. The system of claim 4 wherein said data is temperature data.

24. The system of claim 3 wherein said wireless sensor nodes are mounted on wheel bearing fittings of a railcar on opposite sides of a same axle, and wherein said communication management unit generates a differential temperature alert when

temperatures reported by said wireless sensor nodes on said opposite sides of said axle exceed a differential threshold.

25. The system of claim 23 wherein said communication management unit generates an alert if greater than a certain percentage of the temperature readings received exceed an absolute temperature threshold or an above ambient temperature threshold.

26. The system of claim 23 wherein said communication management unit generates an alert if greater than a certain percentage of temperature readings indicate a temperature rise rate exceeding a certain threshold.

27. The system of claim 3 wherein said communication management unit can instruct each wireless sensor node to enable or disable the checking of individual rules by sending a message to said wireless sensor node.

28. The system of claim 4 wherein said communication management unit can instruct each wireless sensor node to enable or disable the periodic sending of data by sending a message to said wireless sensor node.

29. The system of claim 3 wherein each communication management unit in communication with one or more wireless sensor nodes form a railcar-based mesh network comprising said communication management unit and said wireless sensor nodes, said railcar-based mesh network being controlled by said communication management unit.

30. The system of claim 29 wherein said communication management unit includes wireless sensor nodes from other railcars in its railcar-based mesh network.

31. The system of claim 1 further comprising a powered wireless gateway controlling a train-based network that includes said powered wireless gateway and a plurality of said communication management units.

32. The system of claim 31 wherein said powered wireless gateway serves as said remote receiver.

33. The system of claim 1 wherein said remote receiver is located off-train.

34. The system of claim 33 wherein said communication management unit communicates with said off-train remote receiver via a communication means comprising one of cellular, satellite, WiFi and Bluetooth.

35. A method for detecting operational anomalies on a train consist or railcar comprising the steps of:

a) collecting data regarding said one or more railcar operational parameters;

b) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

c) communicating a message to a remote receiver when said trend or event is detected.

36. The method of claim 35 wherein steps (a) – (c) are performed by a communication management unit located on a railcar in said train consist.

37. The method of claim 36 wherein said data is collected from one or more wireless sensor nodes on said railcar, said wireless sensor nodes being in communication with said communication management unit.

38. The method of claim 37 wherein said communication management unit and said one or more wireless sensor nodes form a railcar-based mesh network.

39. The method of claim 37 wherein said wireless sensor nodes each perform the functions of:

a) collecting data from one or more sensors;

b) comparing said data against one or more rules; and

c) sending a message to said communication management unit when at least one of said rules is satisfied.

40. The method of claim 39 wherein said one or more rules causes data collected from some sensors to be periodically sent to said communication management unit.

41. The method of claim 39 wherein said data includes one or more of the following: acceleration data and temperature data.

42. The method of claim 37 wherein said communication management unit coordinates messages from two or more wireless sensor nodes to confirm that an event has occurred.

43. The method of claim 42 wherein acceleration events are selected from a group consisting of wheel damage, vertical impact, derailment, vertical hunting, lateral hunting and longitudinal impact.

44. The method of claim 42 wherein temperature events include one or more of the following absolute temperature alarm, above ambient temperature alarm, differential temperature alarm, peak analysis alarm, ambient analysis alarm and rate analysis alarm.

45. The method of claim 36 wherein all communication management units on said train consist are configured in a train-based wireless mesh network controlled by a powered wireless gateway.

46. The method of claim 35 wherein said remote receiver is off-train.

47. The method of claim 45 wherein said remote receiver is said powered wireless gateway.

48. The system of claim 1 wherein at least one of said communication management units includes at least one of said sensors.

49. The system of claim 3 wherein one of said wireless sensor nodes comprises:
a) a protective housing;
b) said one or more sensors mounted within said protective housing;
c) a communication capability, for communicating with said communication management unit; and
d) a microprocessor, executing firmware to control the operation of said wireless sensor node.

50. The system of claim 49 wherein said one or more sensors includes a sensor to measure accelerations and wherein said wireless sensor node is tuned to detect certain types of accelerations.

51. The system of claim 50 further comprising a mechanical filter which includes a resilient material selected to filter out undesirable accelerations, said mechanical filter disposed to remove said undesirable accelerations before said undesirable accelerations reach said accelerometer.

52. The system of claim 50 wherein said wireless sensor node further comprises potting material dispose within said housing, said potting material used to tune said wireless sensor node by absorbing undesirable accelerations.

53. The system of claim 49 wherein said firmware includes one or more software filters used to isolate certain types of accelerations.

54. The system of claim 49 wherein said firmware performs the functions of:
a) reading data from said one or more sensors;
b) comparing said data against a set of rules for reporting alerts or events; and

c) communicating an alert or event to said communication management unit when said data meets one or more of said rules.

55. The system of claim 49 wherein said firmware implements an analysis system for detecting events, said analysis system comprising:

a) one or more sensor sections, each of said sensor sections having:

i) a filter, for isolating particular accelerations of interest from data read from one or more acceleration detectors; and

ii) a feature detector, for detecting particular features of interest from said filtered data.

56. A system for detecting operational anomalies on a train consist or railcar comprising:

a) a train-based mesh network comprising a powered wireless gateway and one or more communication management units located on one or more railcars in said train consist;

b) one or more railcar-based mesh networks comprising said one or more communication management units, each arranged in a mesh network configuration with one or more wireless sensor nodes;

c) a distributed complex event processing engine distributed across said wireless sensor nodes, said communication management units and said powered wireless gateway, said distributed complex event processing engine detecting anomalous operating conditions on said train consist via data gathered by sensors controlled by said wireless sensor nodes and propagated upwards through said system.

57. A wireless sensor node configured for attachment to a railcar, comprising:

a. a protective housing;

b. a power source;

c. an accelerometer;

d. electrical circuitry for wireless communications and to control the operation of the wireless sensor node, and

e. said electrical circuitry includes a microprocessor capable of executing firmware with one or more software filters used to isolate certain types of accelerations.

58. The wireless sensor node of claim 57 further comprising a potting material within said housing in which said accelerometer is embedded, said potting material being selected to filter out undesirable accelerations from said railcar.

59. The wireless sensor node of claim 57 further comprising a mechanical filter made of a resilient material selected to filter out undesirable accelerations, and which is positioned to filter out the undesirable accelerations before said accelerations are detected by said accelerometer.

60. A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

a. at least one communication management unit (CMU) mounted on the train consist;

b. at least two sensors located on the railcar for sensing operational parameters of the railcar, said sensors being in communication with said CMU;

c. wherein said CMU performs the following functions:

i) receiving data from said sensors;

ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and

iii) communicating a message to a remote receiver when an anomaly is detected.

61. The system of claim 60 wherein said sensors comprise accelerometers positioned at different locations of the railcar, and wherein said step of drawing inferences comprises the comparison of data from two or more of said accelerometers.

62. The system of claim 60 wherein said sensors comprise temperature sensors positioned at different locations of the railcar, and wherein said step of drawing inferences comprises the comparison of data from two or more said temperature sensors.

63. The system of claim 61 wherein said accelerometers are positioned on the railcar to provide data for carrying out one or more of the following functions:

i) compare accelerations from one railcar wheel with that of another railcar wheel on the same axle but opposite side of the railcar,

ii) compare accelerations from one railcar wheel with that of at least one other wheel on the same side of said railcar, and

iii) compare accelerations from one railcar wheel with that of at least one other railcar wheel on the same side of said one railcar wheel and which other wheel is on another railcar of the same train consist.

64. The system of claim 61 wherein said accelerometers are positioned on the railcar to provide data for carrying out one or more of the following functions:

i) compare accelerations from front and back ends of said railcar,

ii) compare accelerations from any two locations on the railcar, and

iii) compare accelerations from one railcar with those of another in the same train consist.

65. The system of claim 62 wherein said temperature sensors are positioned on the railcar to provide data for comparing temperature data from one railcar wheel bearing with that of another railcar wheel bearing on the same axle but on an opposite side of the railcar.

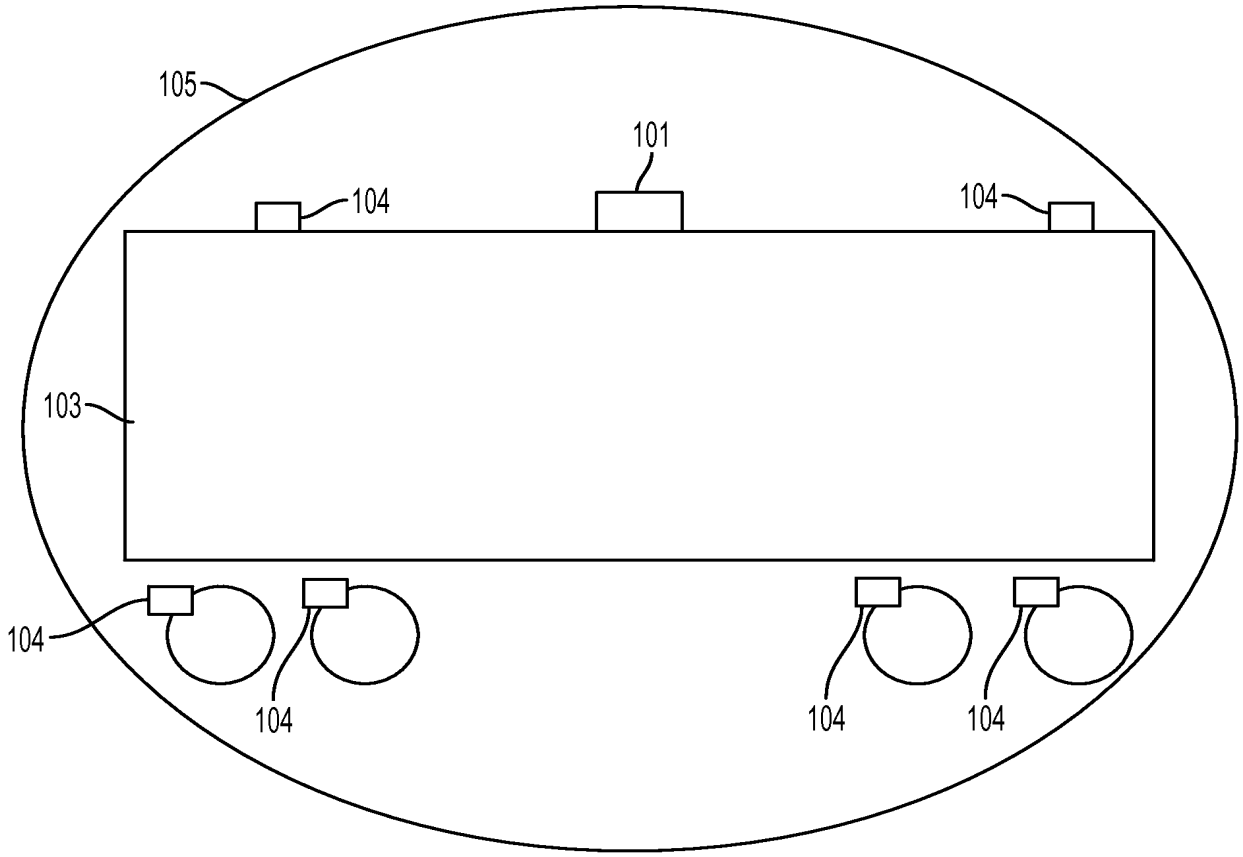


FIG. 1

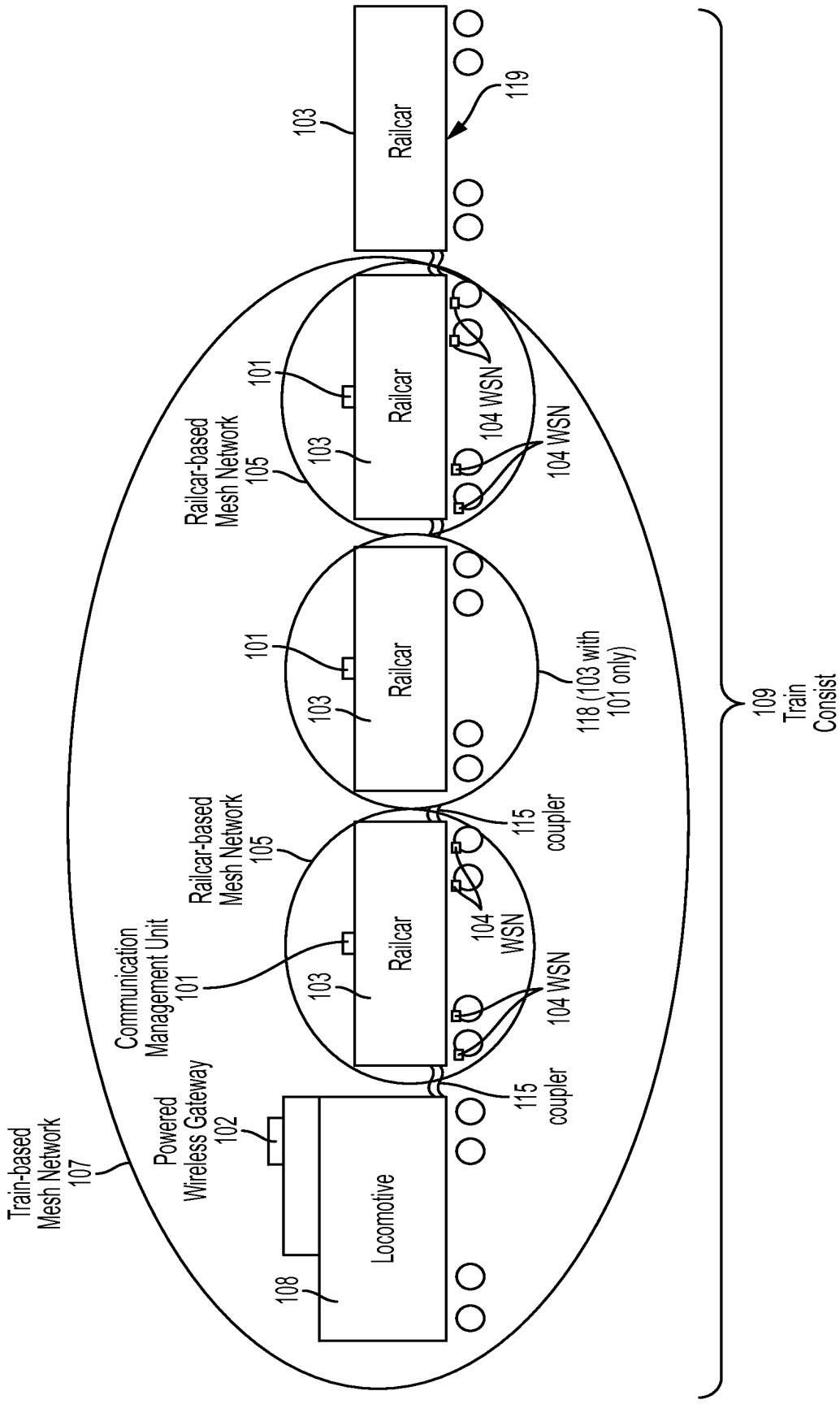

Train-based
Mesh Network
107
Powered
Wireless Gateway
102
Communication
Management Unit
101
Locomotive
108
Railcar-based
Mesh Network
105
Railcar
103
101
104
WSN
104 WSN
115
coupler
118 (103 with
101 only)
119
109
Train
Consist

FIG. 2

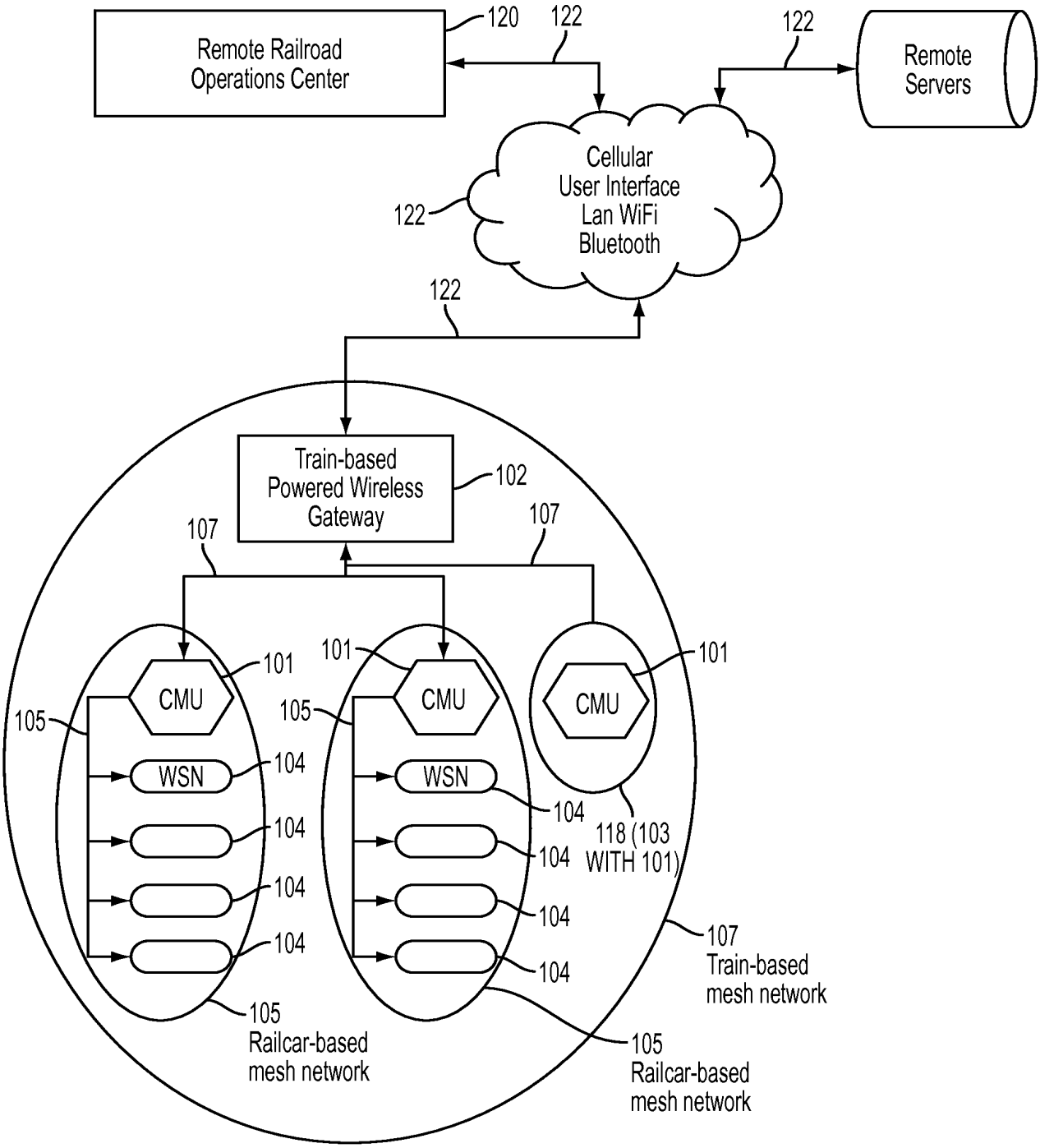

Remote Railroad Operations Center
120
122
122
Remote Servers
Cellular
User Interface
Lan WiFi
Bluetooth
122
122
Train-based Powered Wireless Gateway
102
107
107
101
101
101
CMU
CMU
CMU
105
105
WSN
WSN
104
104
104
104
104
104
104
118 (103 WITH 101)
107
Train-based mesh network
105
Railcar-based mesh network
105
Railcar-based mesh network

FIG. 3

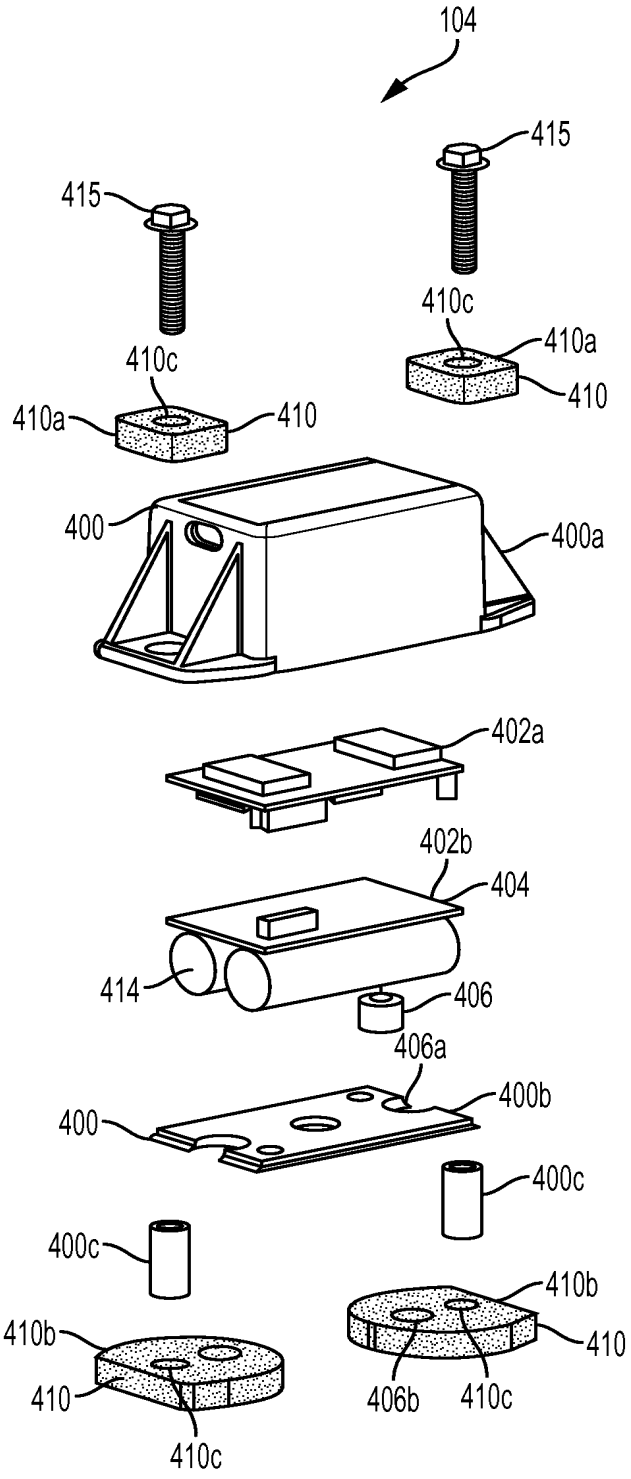

104
415
415
410c
410a
410
410c
410a
410
400
400a
402a
402b
404
414
406
406a
400
400b
400c
400c
410b
410
410b
410
406b
410c
410c

FIG. 4

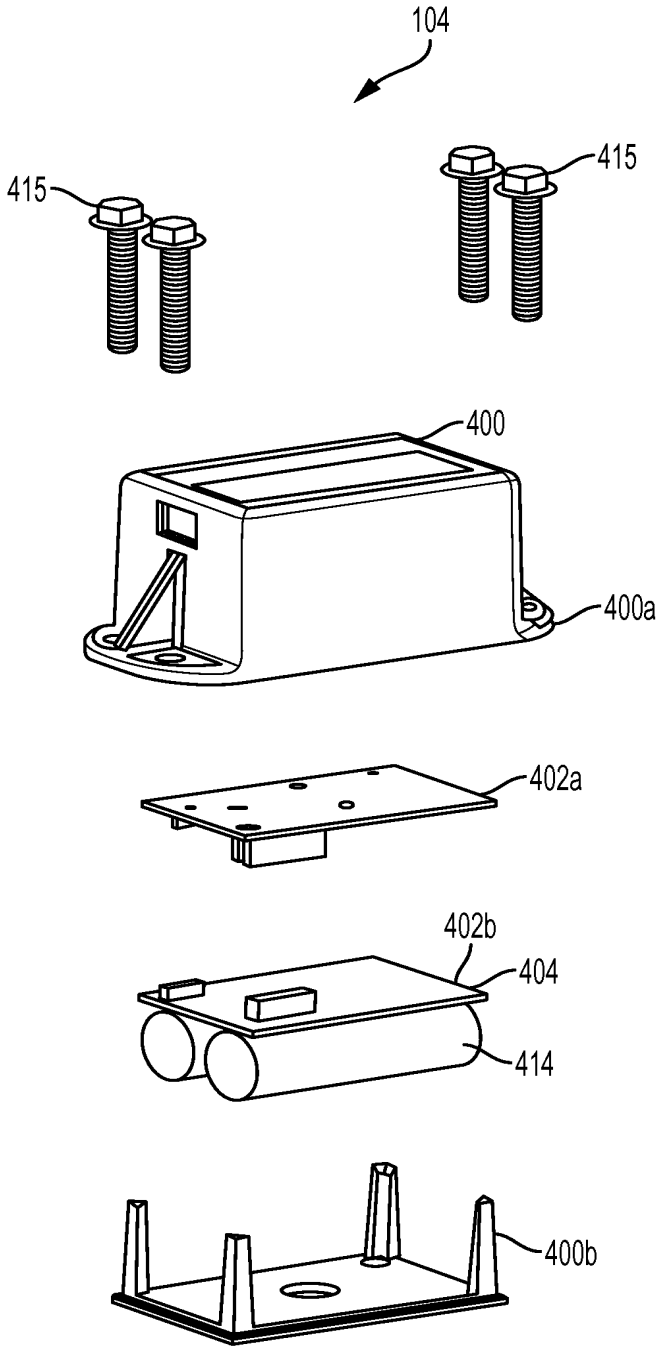


FIG. 5

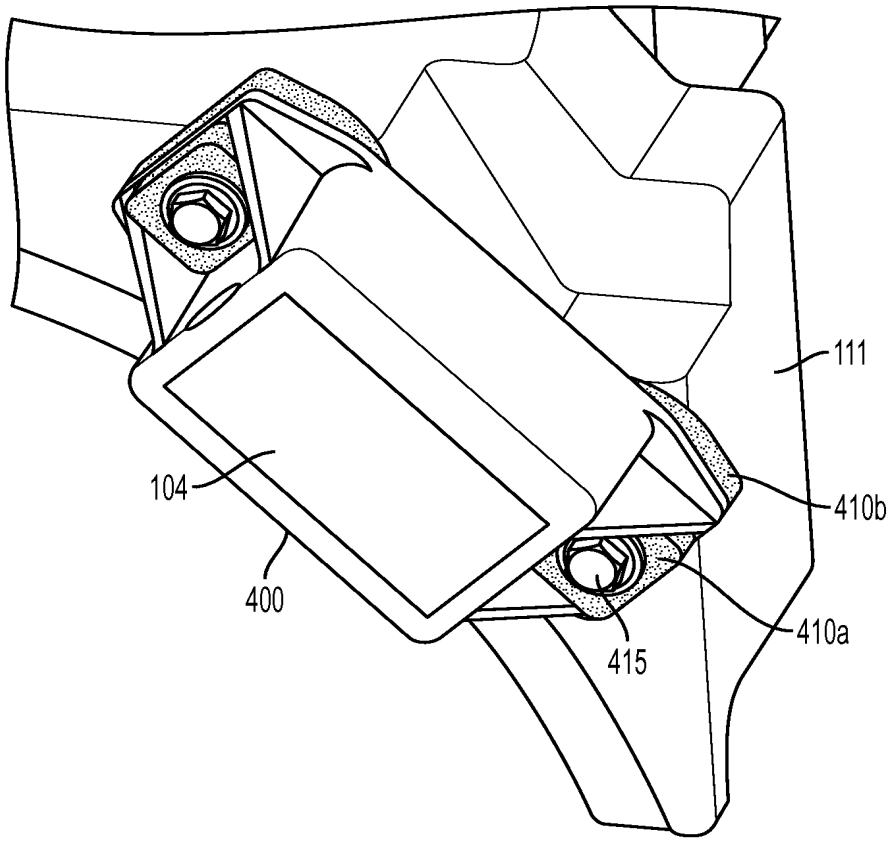


FIG. 6

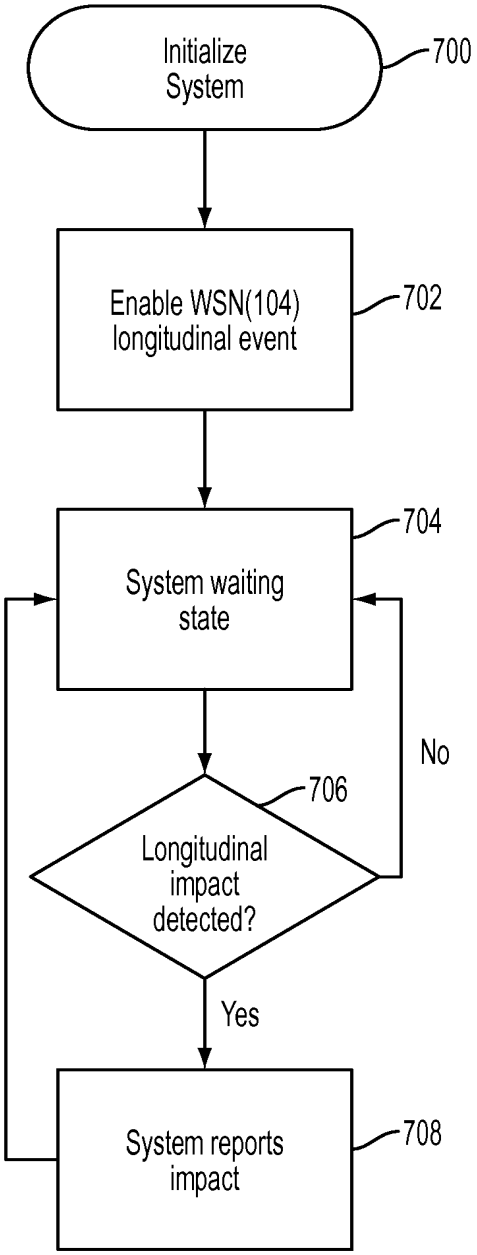

Initialize System
700
Enable WSN(104) longitudinal event
702
System waiting state
704
No
706
Longitudinal impact detected?
Yes
System reports impact
708

FIG. 7

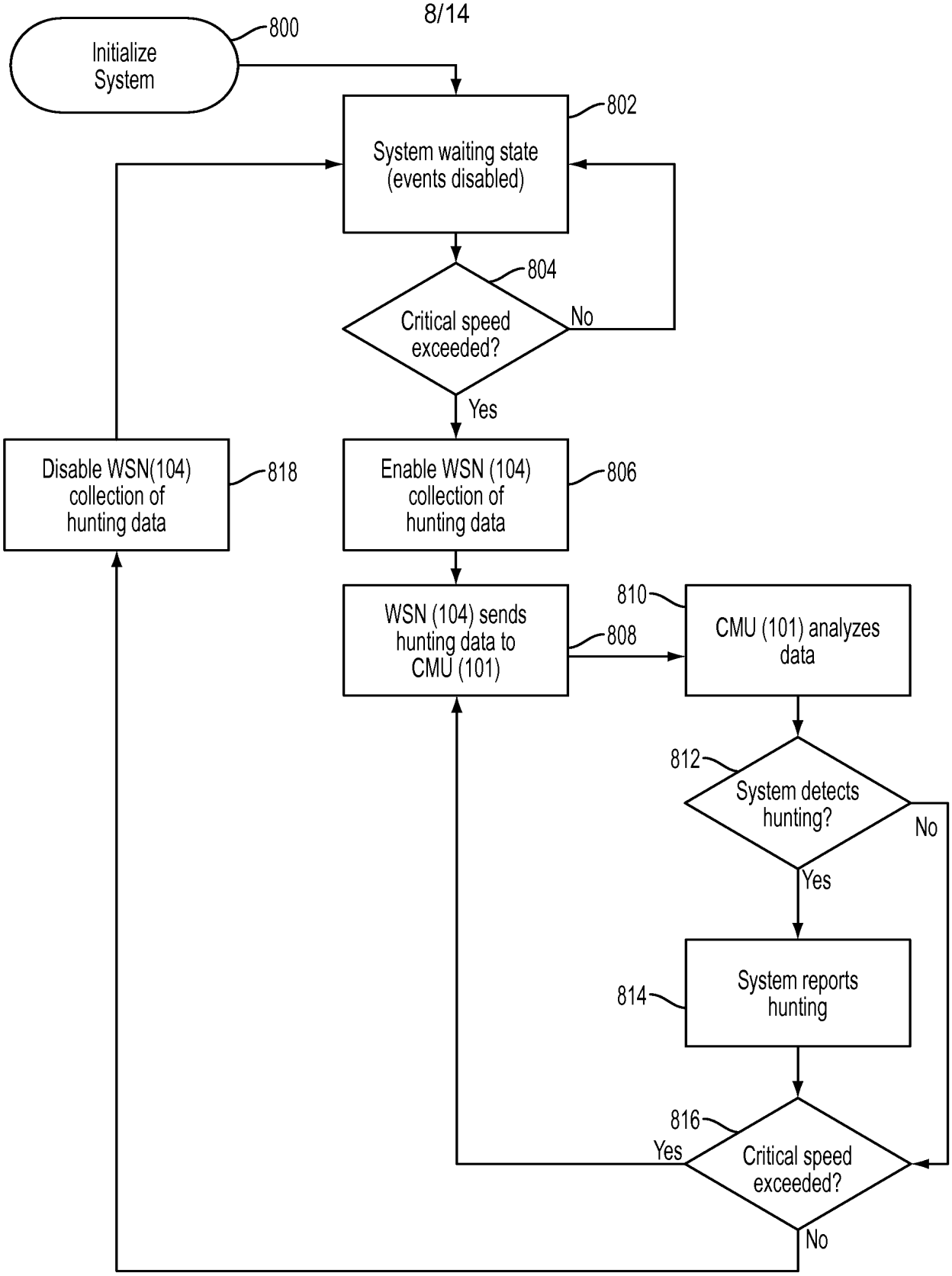

Initialize System
800
System waiting state (events disabled)
802
Critical speed exceeded?
804
No
Yes
Enable WSN (104) collection of hunting data
806
Disable WSN(104) collection of hunting data
818
WSN (104) sends hunting data to CMU (101)
808
CMU (101) analyzes data
810
System detects hunting?
812
No
Yes
System reports hunting
814
Critical speed exceeded?
816
Yes
No

FIG. 8

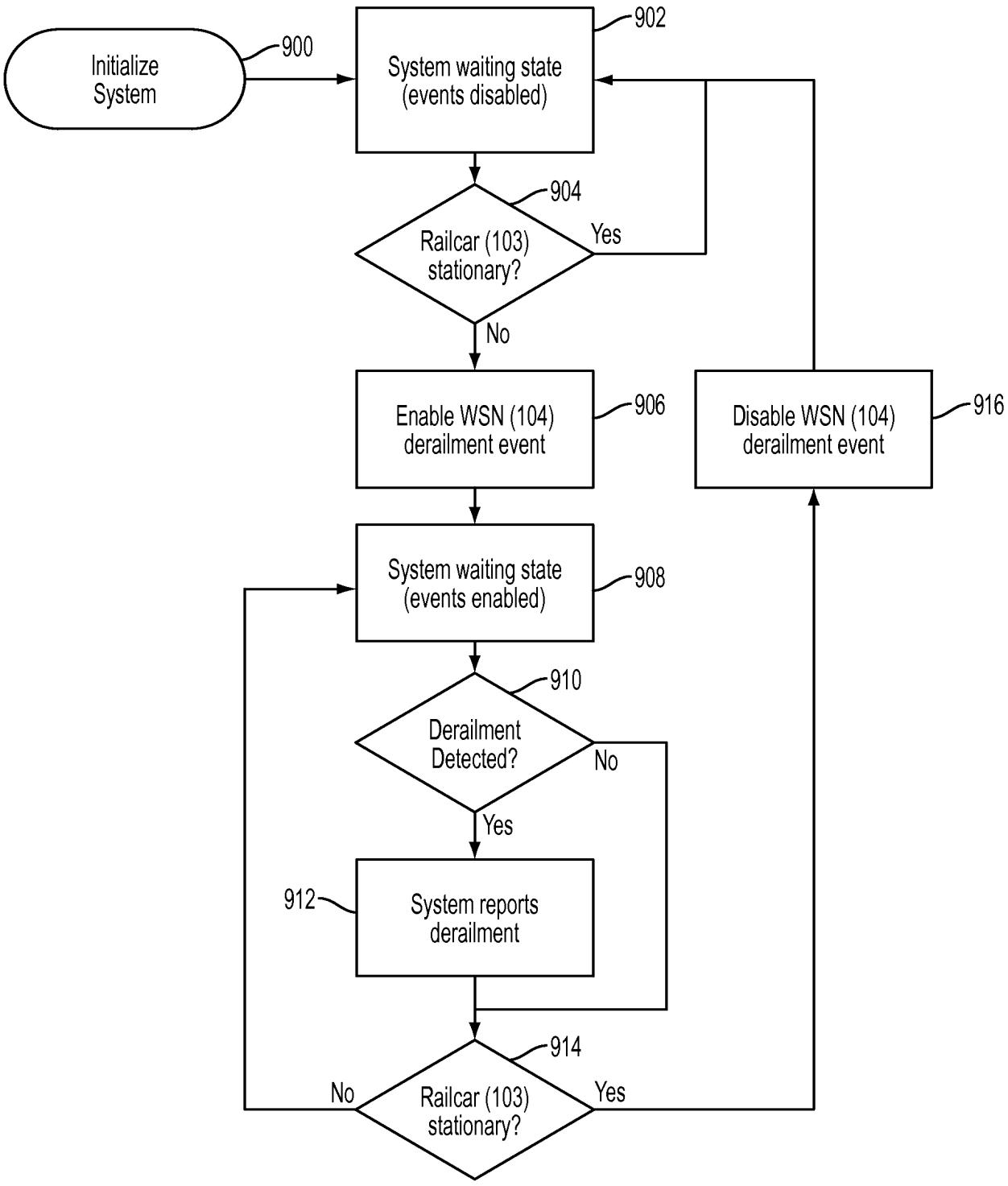

Initialize System
900
System waiting state (events disabled)
902
Railcar (103) stationary?
904
Yes
No
Enable WSN (104) derailment event
906
Disable WSN (104) derailment event
916
System waiting state (events enabled)
908
Derailment Detected?
910
No
Yes
System reports derailment
912
Railcar (103) stationary?
914
No
Yes

FIG. 9

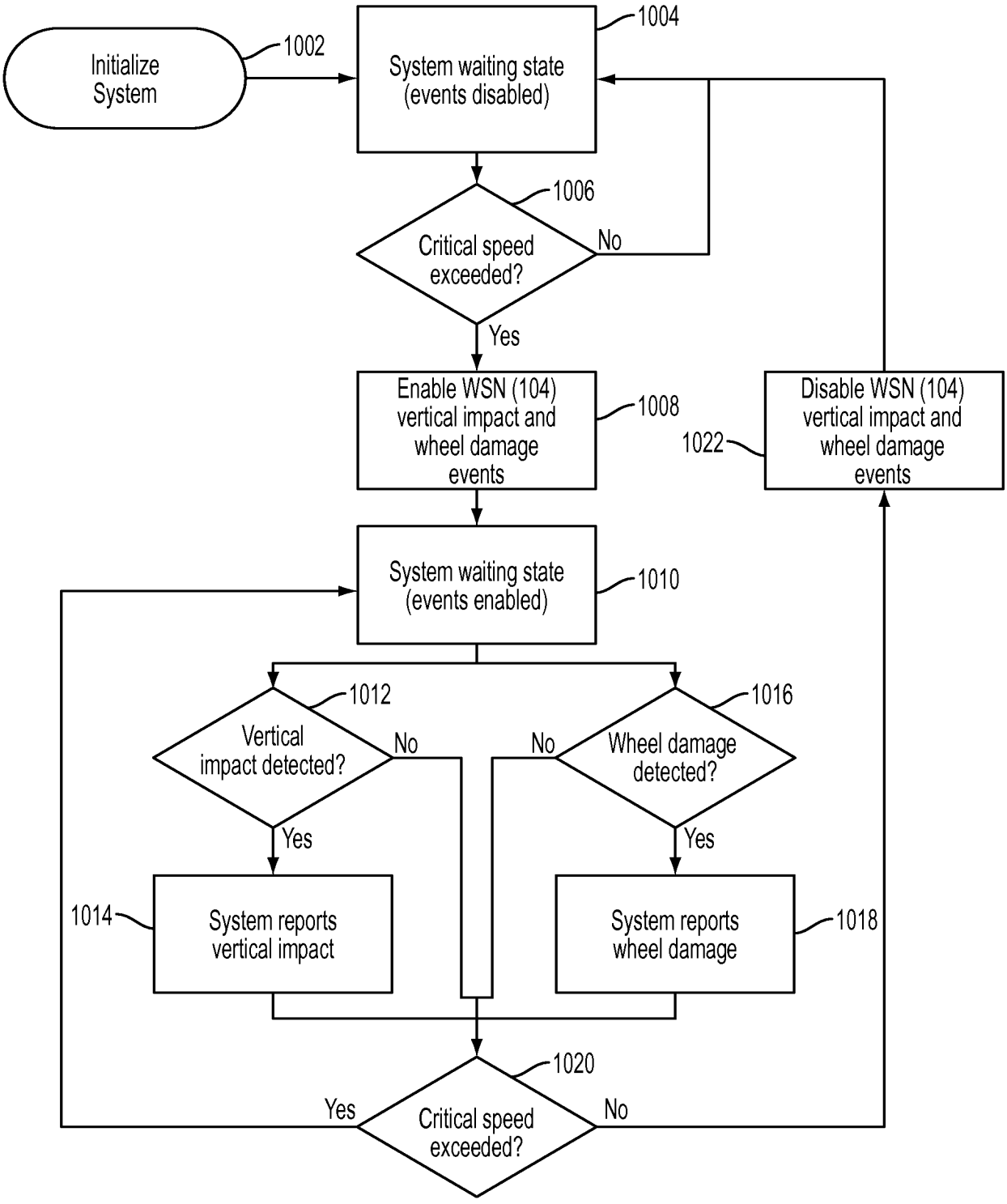

Initialize System
1002
System waiting state (events disabled)
1004
1006
Critical speed exceeded?
No
Yes
Enable WSN (104) vertical impact and wheel damage events
1008
Disable WSN (104) vertical impact and wheel damage events
1022
System waiting state (events enabled)
1010
1012
Vertical impact detected?
No
Yes
1016
Wheel damage detected?
No
Yes
1014
System reports vertical impact
System reports wheel damage
1018
1020
Yes
Critical speed exceeded?
No

FIG. 10

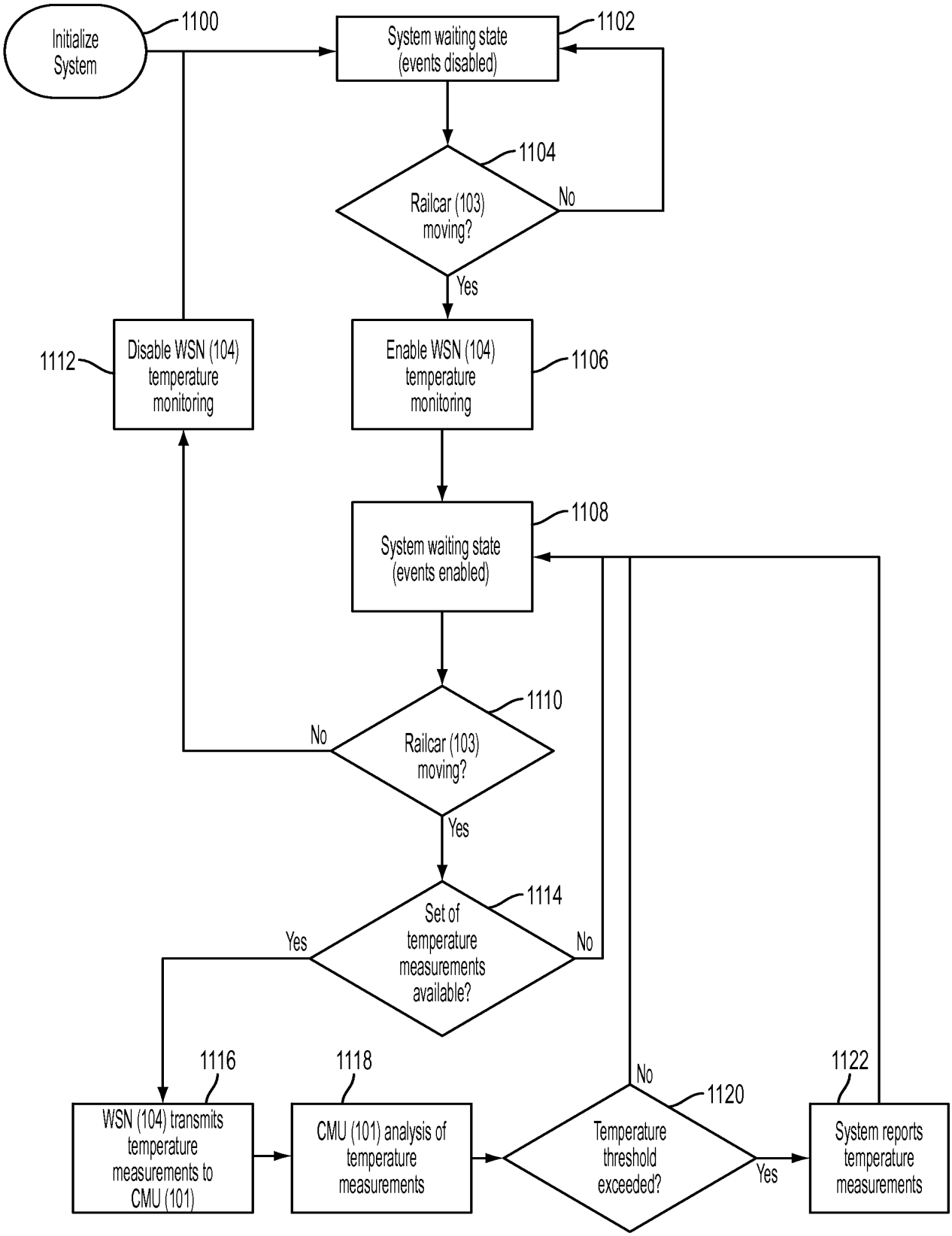

Initialize System
1100
System waiting state (events disabled)
1102
1104
Railcar (103) moving?
No
Yes
1112
Disable WSN (104) temperature monitoring
Enable WSN (104) temperature monitoring
1106
1108
System waiting state (events enabled)
1110
No
Railcar (103) moving?
Yes
1114
Set of temperature measurements available?
Yes
No
1116
1118
No
1120
1122
WSN (104) transmits temperature measurements to CMU (101)
CMU (101) analysis of temperature measurements
Temperature threshold exceeded?
Yes
System reports temperature measurements

FIG. 11

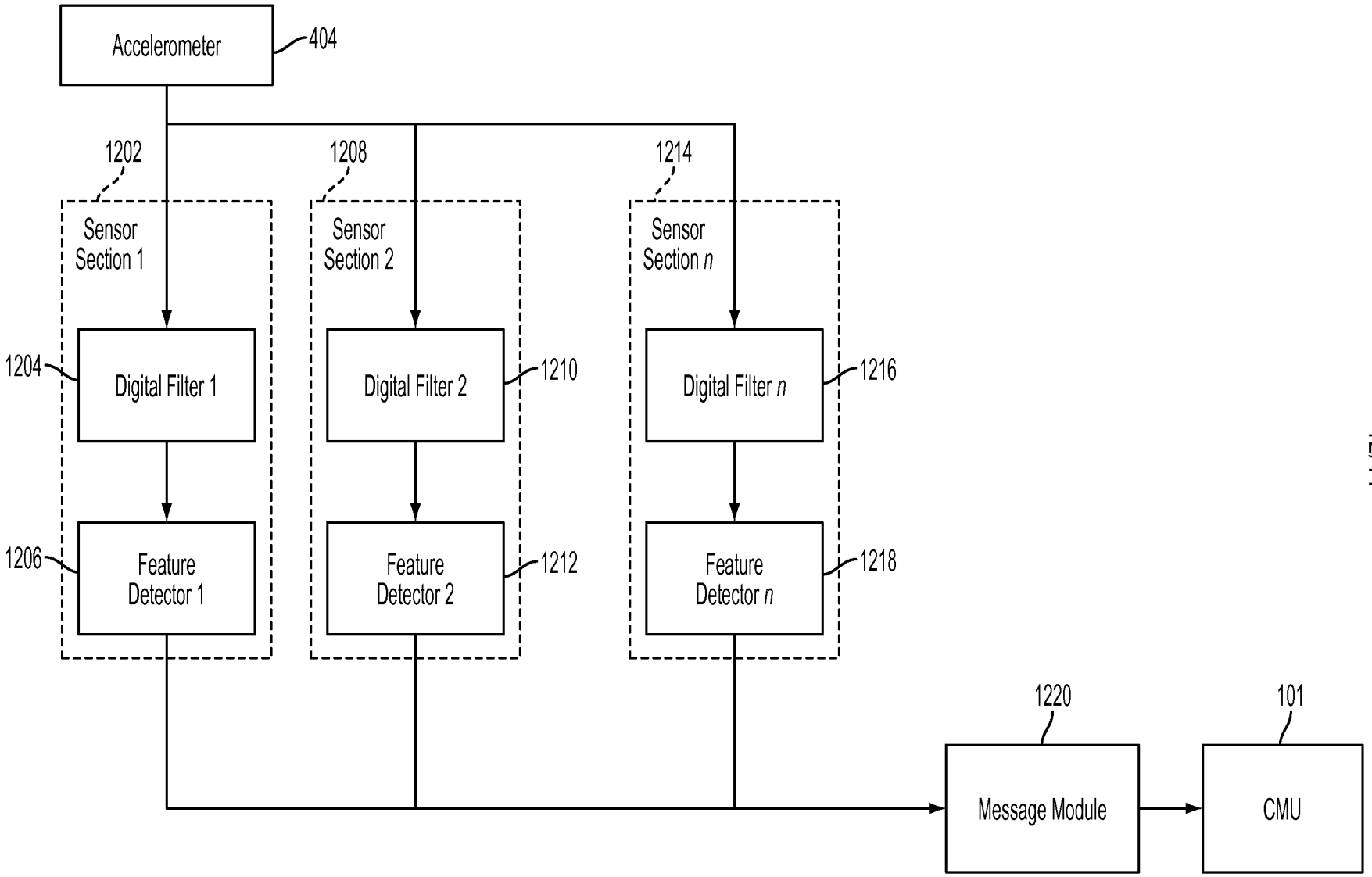


FIG. 12

SUBSTITUTE SHEET (RULE 26)

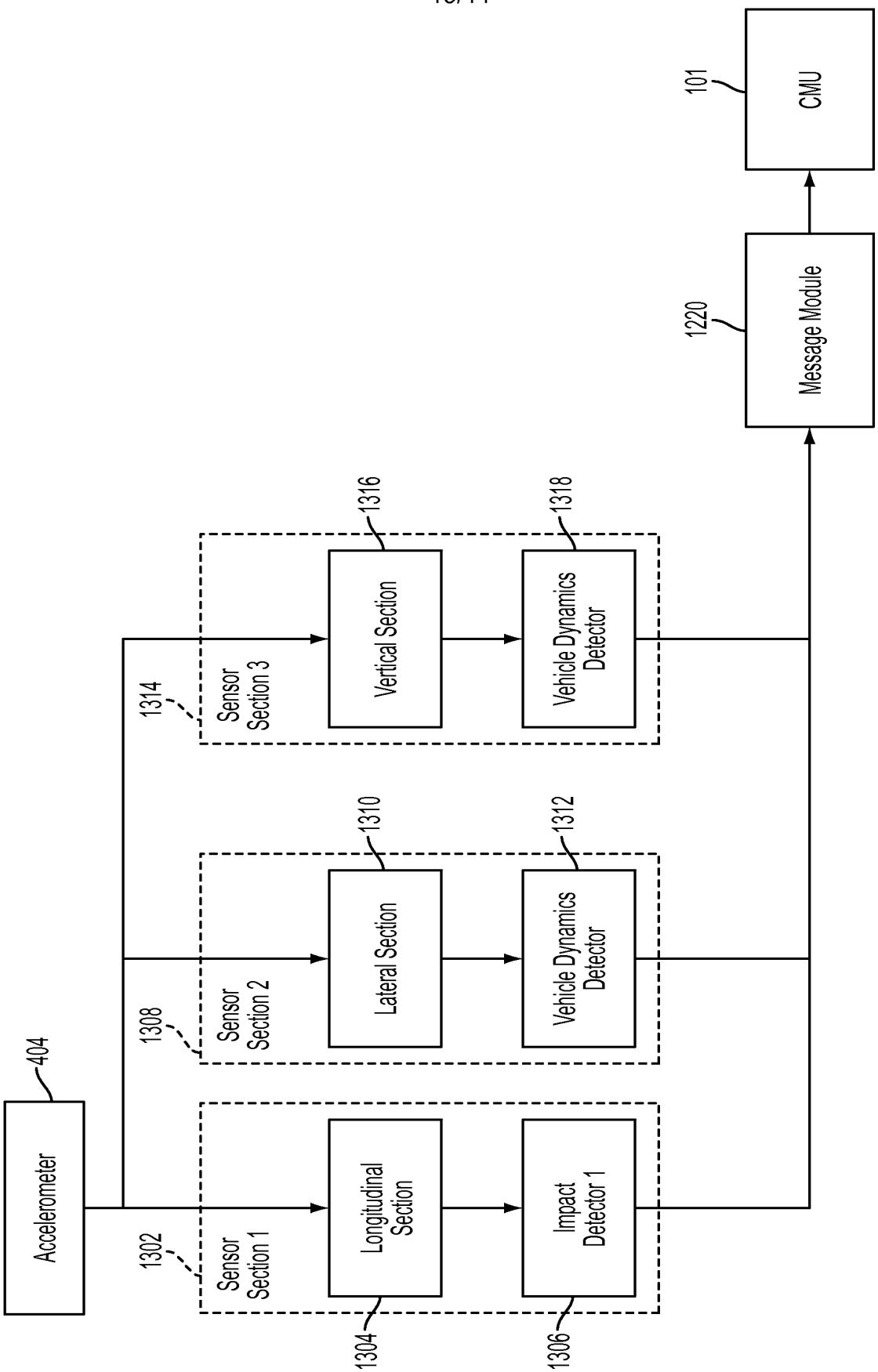

Accelerometer
404
Sensor Section 1
1302
Longitudinal Section
1304
Impact Detector 1
1306
Sensor Section 2
1308
Lateral Section
1310
Vehicle Dynamics Detector
1312
Sensor Section 3
1314
Vertical Section
1316
Vehicle Dynamics Detector
1318
Message Module
1220
CMU
101

FIG. 13

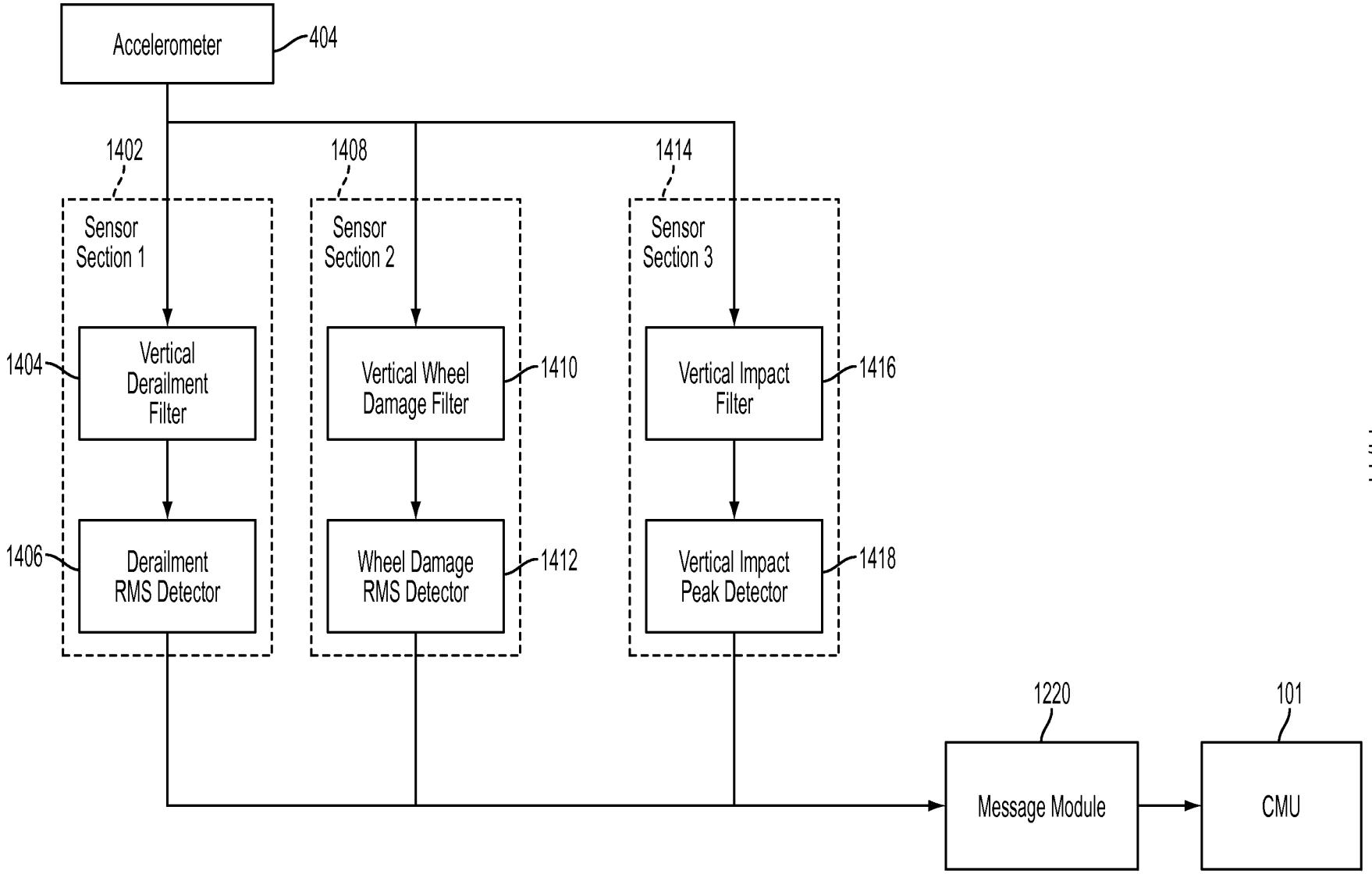


FIG. 14

SUBSTITUTE SHEET (RULE 26)

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 15/108,065	Filing Date 06/24/2016	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT 06/24/2016

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 31	Minus	** 31	= 0	X $80 =	0
Independent (37 CFR 1.16(h))	* 4	Minus	***4	= 0	X $420 =	0
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	0

AMENDMENT

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
DIANE FLOYD

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

U.S. APPLICATION NUMBER NO.	FIRST NAMED INVENTOR	ATTY. DOCKET NO.
15/108,065	William LeFebvre	P37056A US (37659.00060)

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

INTERNATIONAL APPLICATION NO.	
PCT/US14/72380	
I.A. FILING DATE	PRIORITY DATE
12/24/2014	12/24/2013

CONFIRMATION NO. 1019
371 ACCEPTANCE LETTER

OC000000084726959

Date Mailed: 08/01/2016

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office, in its capacity as a Designated / Elected Office (37 CFR 1.495), has ACCEPTED the above identified international application for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above. A Filing Receipt will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE "FILING DATE or 371(c) DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1) and (c)(2) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN BELOW.** The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363)

06/24/2016
DATE OF RECEIPT OF 35 U.S.C.
371(c)(1) and (c)(2) REQUIREMENTS

The following items have been received:

- Copy of the International Application filed on 06/24/2016
- Copy of the International Search Report filed on 06/24/2016
- Preliminary Amendments filed on 06/24/2016
- Inventor's Oath or Declaration filed on 06/24/2016
- Request for Immediate Examination filed on 06/24/2016
- U.S. Basic National Fees filed on 06/24/2016
- Assignment filed on 06/24/2016
- Assignee Statement for PGPUB filed on 06/24/2016
- Priority Documents filed on 06/24/2016
- Power of Attorney filed on 06/24/2016
- Application Data Sheet (37 CFR 1.76) filed on 06/24/2016

FORM PCT/DO/EO/903 (371 Acceptance Notice)

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

CHERRIE M HAYWOOD

Telephone: (703) 756-1144

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/108,065	06/24/2016		2420	P37056A US (37659.00060)	31	4

CONFIRMATION NO. 1019

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

FILING RECEIPT

OC000000084726938

Date Mailed: 08/01/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

William LeFebvre, West Chester, PA;
Andrew Martin, West Chester, PA;
Francis James COOPER, Downingtown, PA;
Rachel W. ADAMEC, Norristown, PA;

Applicant(s)

AMSTED RAIL COMPANY, INC., Chicago, IL;

Assignment For Published Patent Application

Amsted Rail Company, Inc., Chicago, IL

Power of Attorney: The patent practitioners associated with Customer Number 29880

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/US14/72380 12/24/2014
which claims benefit of 61/920,700 12/24/2013

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: No

Permission to Access Search Results: No

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 07/28/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/108,065**

Projected Publication Date: 11/10/2016

Non-Publication Request: No

Early Publication Request: No

Title

SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop

technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/108,065

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	120
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	31 minus 20 =	* 11			OR	x 80 =	880
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1				x 420 =	420
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	2420

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET

Substitute for Form PTO-1360
(For use with Form PTO/SB/06)

Application Number	Filing Date
15108065	

Applicant(s) William LeFebvre

* May be used for additional claims or amendments

CLAIMS	AS FILED		AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT	
	Indep	Depend	Indep	Depend	Indep	Depend
1	1		1			
2		1		1		
3		1	---	---		
4		1		1		
5		1		1		
6		1	---	---		
7		1	---	---		
8		1		1		
9		1		1		
10		1		1		
11		1		1		
12		1		1		
13		1		1		
14		1		1		
15		1		1		
16		1		1		
17		1		1		
18		1		1		
19		1		1		
20		1		1		
21		1		1		
22		1	---	---		
23		1	---	---		
24		1	---	---		
25		1	---	---		
26		1	---	---		
27		1		1		
28		1		1		
29		1	---	---		
30		1	---	---		
31		1		1		
32		1	---	---		
33		1	---	---		
34		1	---	---		
35	1		1			
36		1		1		
37		1	---	---		
38		1	---	---		
39		1		1		
40		1	---	---		
41		1	---	---		
42		1		1		
43		1	---	---		
44		1	---	---		
45		1		1		
46		1	---	---		
47		1	---	---		
48		1	---	---		
49		1		1		
50		1	---	---		
Total Indep	5		4		0	
Total Depend	60	↵	27	↵	0	↵
Total Claims	65		31		0	

	*		*		*	
	Indep	Depend	Indep	Depend	Indep	Depend
51		1	---	---		
52		1		1		
53		1	---	---		
54		1	---	---		
55		1	---	---		
56	1		1			
57	1		---	---		
58		1	---	---		
59		1	---	---		
60	1		1			
61		1		1		
62		1	---	---		
63		1	---	---		
64		1	---	---		
65		1	---	---		
66						
67						
68						
69						
70						
71						
72						
73						
74						
75						
76						
77						
78						
79						
80						
81						
82						
83						
84						
85						
86						
87						
88						
89						
90						
91						
92						
93						
94						
95						
96						
97						
98						
99						
100						

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)

CONFIRMATION NO. 1019

29880
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

PUBLICATION NOTICE



Title:SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

Publication No.US-2016-0325767-A1
Publication Date:11/10/2016

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. LeFebvre et al.
Art Unit	
Examiner Name	
Attorney Docket Number	037659.00060

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3718040		1973-02-27	Freeman et al.	
	2	5446451		1995-08-29	Grosskopf, Jr.	
	3	5603556		1997-02-18	Klink	
	4	5682139		1997-10-28	Pradeep et al.	
	5	5691980		1997-11-25	Welles, II et al.	
	6	6175784	B1	2001-01-16	Jicha et al.	
	7	6184798	B1	2001-02-06	Egri	
	8	6301531	B1	2001-10-09	Pierro et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. LeFebvre et al.
	Art Unit	
	Examiner Name	
	Attorney Docket Number	037659.00060

	9	6339397	B1	2002-01-15	Baker	
	10	6668216	B2	2003-12-23	Mays	
	11	7336156	B2	2008-02-26	Arita et al.	
	12	7688218	B2	2010-03-30	LeFebvre et al.	
	13	7698962	B2	2010-04-20	LeFebvre et al.	
	14	8244411	B2	2012-08-14	Baker	
	15	8370006	B2	2013-02-05	Kumar et al.	
	16	8672273	B2	2014-03-18	Brown et al.	
	17	8751290	B2	2014-06-10	Schullian et al.	
	18	9365223	B2	2014-06-14	Martin et al.	
	19	9663092	B2	2017-05-30	Martin et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. LeFebvre et al.
	Art Unit	
	Examiner Name	
	Attorney Docket Number	037659.00060

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20090001226	A1	2009-01-01	Haygood	
	2	20100200307	A1	2010-08-12	Toms	
	3	20050259619	A1	2005-11-24	Boettle et al.	
	4	20060264221	A1	2006-11-23	Koike et al.	
	5	20070241610	A1	2007-10-18	Smith	
	6	20080195265	A1	2008-08-14	Searle et al.	
	7	20090173840	A1	2009-07-09	Brown et al.	
	8	20110270475	A1	2011-11-03	Brand et al.	
	9	20110282540	A1	2011-11-17	Armitage et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. LeFebvre et al.
	Art Unit	
	Examiner Name	
	Attorney Docket Number	037659.00060

FOREIGN PATENT DOCUMENTS								Remove
Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	1548419	EP	A1	2005-06-29	NSK Ltd.		
	2	2650191	EP	A1	2013-10-16	Progress Rail Services Corporation		
	3	05213195	JP	A	1993-08-24	Sumitomo Metal Ind Ltd		
	4	05343294	JP		1993-12-24	NEC Corp		
	5	08015099	JP		1996-01-19	Sumitomo Metal Ind Ltd		
	6	10217968	JP		1998-08-18	Toshiba Corp		
	7	11192948	JP		1999-07-21	Toshiba Corp		
	8	2001015001	WO	A2	2001-01-03	General Electric Company		
	9	2005105536	WO	A1	2005-10-11	Sti Rail Pty Ltd		
If you wish to add additional Foreign Patent Document citation information please click the Add button								Add
NON-PATENT LITERATURE DOCUMENTS								Remove

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. LeFebvre et al.
	Art Unit	
	Examiner Name	
	Attorney Docket Number	037659.00060

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. LeFebvre et al.
	Art Unit	
	Examiner Name	
	Attorney Docket Number	037659.00060

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2017-09-29
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 548 419 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
29.06.2005 Bulletin 2005/26

(21) Application number: **03797537.2**

(22) Date of filing: **29.08.2003**

(51) Int Cl.[7]: **G01M 13/04**, G01M 19/00, G01M 17/08, F16C 41/00, B61F 15/20, G01D 21/00, G01B 21/00

(86) International application number:
PCT/JP2003/011114

(87) International publication number:
WO 2004/027370 (01.04.2004 Gazette 2004/14)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

(30) Priority: **30.08.2002 JP 2002252877**
21.11.2002 JP 2002338423
20.12.2002 JP 2002370800
17.01.2003 JP 2003010131
25.02.2003 JP 2003048309
26.06.2003 JP 2003182996
28.08.2003 JP 2003304700

(71) Applicant: **NSK Ltd.**
Tokyo 141-8560 (JP)

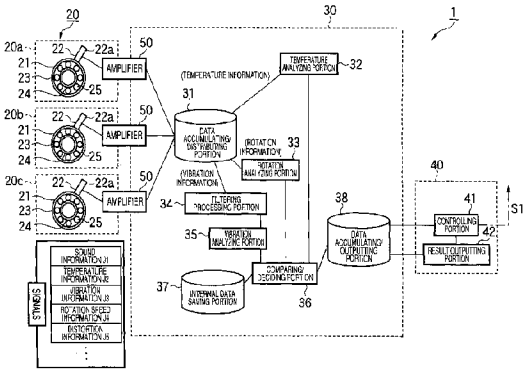
(72) Inventors:
- **MIYASAKA, Takanori, NSK Ltd.**
Fujisawa-shi, Kanagawa 251-8501 (JP)
- **ARAMAKI, Hirotoshi, NSK Ltd.**
Fujisawa-shi, Kanagawa 251-8501 (JP)
- **MUTOU, Yasushi, NSK Ltd.**
Fujisawa-shi, Kanagawa 251-8501 (JP)
- **SAHARA, Juntaro, NSK Ltd.**
Fujisawa-shi, Kanagawa 251-8501 (JP)

(74) Representative: **Grünecker, Kinkeldey,**
Stockmair & Schwanhäusser Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) METHOD AND DEVICE FOR MONITORING STATUS OF MECHANICAL EQUIPMENT AND ABNORMALITY DIAGNOSING DEVICE

(57) An abnormality diagnosis system for diagnosing a presence or absence of an abnormality of a bearing unit for a railway vehicle axle, comprises a sensing/processing portion for outputting a signal generated from the bearing unit as an electric signal, a calculating/processing portion for making an abnormality diagnosis of the bearing unit based on an output of the sensing/processing portion, a result outputting portion for outputting a decision result of the calculating/processing portion, and a controlling/processing portion for feeding back a control signal to a control system of the railway vehicle based on the decision result.

FIG. 1



EP 1 548 419 A1

Printed by Jouve, 75001 PARIS (FR)

Description

<Technical Field>

[0001] The present invention relates to a machinery facility condition monitoring method and system and an abnormality diagnosis system and, more particularly, a machinery facility condition monitoring method and system and an abnormality diagnosis system capable of monitoring conditions such as an abnormality, and so forth in a machinery facility such as a railway vehicle facility, a machine tool, a windmill, a reduction gear, an electric motor, or the like including at least one of a rotating body and a sliding member such as a rolling bearing, a sliding bearing, a ball screw, a linear guide, a linear ball bearing, and the like without decomposition of the machinery facility.

<Background Art>

[0002] In the prior art, in order to prevent generation of the failure due to the wear or the failure of the rotating body or the sliding member, a thorough overhaul and a visual inspection are applied periodically to the machinery facility such as the railway vehicle facility, the machine tool, the windmill, or the like. In the thorough overhaul and the visual inspection, the rotating body or the sliding member is removed from the machinery facility and decomposed after the facility is operated for a predetermined period, and then the skilled expert who handling the inspection checks a degree of the wear, the presence or absence of the flaw, or the like of respective constituent parts with a skilled eye. As major defects that are found by the inspection, in the case of the bearing unit, there are the indentation due to the capture of the foreign matter, etc., the flaking due to the rolling contact fatigue, other wear, and others. Also, in the case of the gear, there are the fracture or wear of the teeth, or the like. When the person who handles an inspection detects an abnormality such as unevenness, wear, and the like., which are not found in a new rotating body or sliding member, such person exchanges the defective parts for the new one and then assembles the rotating body or the sliding member once again (see the catalog "ROLLING BEARING" (CAT.No.1101e, page B340 to page B351) issued by Nippon Seiko K.K.).

[0003] However, in the method of decomposing the overall machinery facility and inspecting the failure with the eye of the person in charge, a decomposing operation of removing the rotating body or the sliding member from the machinery facility and a fitting operation of fitting again the inspected rotating body or sliding member into the machinery facility require much time and labor. Thus, such a problem existed that a substantial increase in an upkeep cost required for maintaining, managing, or the like the machinery facility is brought upon.

[0004] In particular, in the case of the windmill, most of the windmills are used in an offshore area and also the number of the installed windmills is large. It is the existing circumstances of maintaining/managing operations of the windmill that the person in charge of the maintenance goes to the installation location of the windmill and then conducts the inspection of rotating parts of the windmill there. For this reason, such a problem existed that it take an enormous time and cost to maintain/manage the windmill and thus a maintenance efficiency is poor. Also, it is possible that the inspection itself causes the defect of the rotating body or the sliding member. For instance, the indentation that has not been put before the inspection is made on the rotating body or the sliding member when the machinery facility is reassembled after the decomposition and the inspection, and so forth. Also, since the person in charge of the inspection must check a number of bearings with the eye within a limited time, there existed the problem that such a possibility still remains that such person fails to find the defect. In addition, since a decision level of the defect varies between individuals and thus exchange of the parts is carried out even though the defect is not found substantially, the above inspection entails a useless cost.

[0005] Also, in order to overcome the disadvantages caused by such visual inspection, it is studied that the sensor for sensing the sound or the vibration generated during the rotation of the bearing is provided on the body of the vehicle in which the bearing is used, and then the abnormality such as the wear, the failure, or the like of the bearing is sensed based on the sensed signal of the sensor.

[0006] However, in the case where the sensor is fitted onto the body of the vehicle, an SN ratio of the sensed signal from the sensor is worsened because the sensor is provided away from the bearing. Thus, there existed such a problem that it is difficult to sense/decide the abnormality with high precision.

[0007] Also, as an bearing unit in the prior art, in a bearing unit 1100 having a sensor module shown in FIG.50, a module hole 1103 is formed on an outer peripheral surface of an outer ring 1102 of a rolling bearing 1101, and then a module 1104 into which a speed sensor, a temperature sensor, and an acceleration sensor are installed is inserted/fixed into the module hole 1103. Then, sensed signals generated from respective sensors in the module 1104 are transmitted to a remote processing unit provided in the locomotive, which pulls the freight cars and the passenger cars in which the rolling bearings 1101 are provided, via the communication channel.

[0008] As to the speed, the instantaneous speed of the journal is sensed based on the pulse generated by the rotating wheel, and then such speed and the speed of other bearings that are operating under the same conditions are compared

with each other. Thus, the overall period history to which the bearing assembly is subjected is saved/recorded. As to the temperature, such temperature and the temperature of other bearings that are operating under the same conditions are compared with each other by a simple level detection. As to the vibration, a simple RMS measurement of an energy level is carried out over a predetermined period of time, and then such energy level and the past energy level stored in a processing unit are compared with each other. Thus, such energy level and the energy level of other bearings that are operating under the same conditions are compared with each other (see JP-T-2001-500597 (pp.10 to 16, Fig.1)).

[0009] Also, as another configurative example of the bearing unit, in an abnormality sensing unit 1110 of the rolling bearing unit shown in FIG.51, a sensor fitting hole 1113 is formed in the lower end portion of an outer ring 1112 of a double row tapered roller bearing 1111, and then a sensor unit 1117 having a rotation speed sensor 1114, a temperature sensor 1115, and an acceleration sensor 1116 therein is inserted/supported into the sensor fitting hole 1113 (for example, see 1P-A-2002-295464 (pp.4 to 5, Fig.1)).

[0010] In addition, as other configurative example of the bearing unit, in a sensor built-in rotation supporting member 1120 shown in FIG.52, a sensor fitting hole 1123 is formed in the lower end portion of an outer ring 1122 of a double row tapered roller bearing 1121, and then a sensor unit 1126 having a rotation speed sensor 1124 and a temperature sensor 1125 therein is inserted/supported into the sensor fitting hole 1123 (for example, see JP-A-2002-292928 (pp. 4 to 5, Fig.1)).

[0011] Further, as other configurative example, an abnormality sensing unit 1130 of the bearing unit shown in FIG. 53 has a pickup 1132 for converting a mechanical vibration of a bearing 1131 into an electric vibration to output, an automatic gain control amplifier 1133 for amplifying an output of the pickup 1132, and a 1 to 15 kHz bandpass filter 1134 for removing noises generated from the driving system and other mechanical systems from the output of the amplifier 1133. Also, the unit 1130 has a root- mean-square calculator 1135 for calculating a root mean square value of the output of the bandpass filter 1134 and supplying the value to a gain control terminal of the automatic gain control amplifier 1133, an envelope circuit 1136 for receiving an output of the bandpass filter 1134, a root-mean-square calculator 1137 for receiving an output of the envelope circuit 1136, and an alarm circuit 1138 for receiving an output of the root-mean-square calculator 1137 and issuing an alarm by using a lamp or a contact output when such output value exceeds a predetermined value (for example, see JP-A-2-205727 (pp.2 to 3, Fig.1)).

[0012] Furthermore, as other configurative example, an abnormality diagnosis system 1140 of the rolling bearing shown in FIG.54 has a configuration that includes a microphone 1142 arranged in vicinity of a rolling bearing 1141, an amplifier 1143, an electronic device 1144, a speaker 1145, and a monitor 1146. The electronic device 1144 is a calculating/processing unit, and has a transducer 1147 as a converting portion, a HDD 1148 as a recording portion, an abnormality diagnosing portion 1149 as a calculating/processing portion, and an analog converting/outputting portion 1150 (for example, see JP-A- 2000-146762 (pp.4 to 6, Fig.1)).

[0013] Besides, as other configurative example, in an abnormality diagnosing method and an abnormality diagnosing system 1160 of the bearing shown in FIG.55, an electric signal waveform that a sensor 1161 outputs is converted into the digital file by an analog/digital converter 1162, then is sent out to a waveform processing portion 1163, and then is subjected to the enveloping process by the waveform processing portion 1163 to get an envelope spectrum. Then, an inner ring flaw component, an outer ring flaw component, and a rolling element flaw component, which are particular frequency components of the bearing constituent parts, are extracted from the envelope spectrum by the waveform processing portion 1163 in the extracting step by using predetermined equations. Then, a calculating portion 1164 executes the calculating step, a deciding portion 1165 executes the comparing step, an outputting portion 1166 outputs the decided result, and a speaker 1167 and a monitor 1168 inform the inspector of the result (for example, see JP-A-2001-021453 (pp.5 to 6, Fig.1)).

[0014] However, in the configurations of the bearing unit set forth in JP-T-2001-500597 and JP-A-2002-295464, since the sensor fitting hole is provided in the outer ring, the type of the outer rings constituting the bearing is increased such as the outer ring in which the hole is not provided and the outer ring in which the hole is provided. As a result, there is a possibility of generating the installing error, and the like, and also a lot of man-hours are needed to manage the parts. Also, it is possible that the outer ring with the hole hinders the sealing performance in the bearing.

[0015] Also, in the abnormality diagnosis system set forth in JP-A-2-205727, JP-A-2000-146762, and JP-A-2001-021453, merely the measure against the vibration noise is disclosed. In the case where the bearing is used to support the axle of the railway vehicle, it is possible that this diagnosis system decides a great shock generated when the railway vehicle passes over the rail joint as an abnormal signal. Thus, the abnormality decision may be largely affected.

[0016] Also, in order to overcome the disadvantages caused by the overhaul inspection or the visual inspection, there is proposed a monitoring system that includes a sensor for sensing the sound or the vibration generated during the rotation of the bearing and an information processing system for analyzing a sensed signal of the sensor to decide whether or not the abnormality is generated and uses a personal computer as the information processing system (for example, see JP-A-2002- 71519).

[0017] However, the personal computer used as the information processing system in the monitoring system in the

prior art has normally such a configuration that a motherboard and an interface for receiving an output of the sensor are installed into a general-purpose casing. Thus, the information processing system needs a relatively large installing space and also has a tendency that does not endure the vibration, and the like well.

[0018] For this reason, in order to prevent an influence of the vibration on the bearing unit, etc., a space in which the personal computer is provided must be secured in the position that is distant from the bearing unit, etc. to some extent. In addition, this monitoring system becomes large in size. Therefore, in the case of the machinery facility in which the assurance of the large installing space is difficult, such a problem has arisen that such monitoring system is of little utility.

[0019] Also, in order to prevent a deterioration of the SN ratio of the signal sensed by the sensor, it is preferable that the sensor should be incorporated into the constituent parts itself of the bearing unit if possible. However, the personal computer that cannot stand up to the external vibration, and the like and is large in size must be separated as far as possible away from the bearing unit, or the like as the vibration generating source. As a result, the personal computer is apart from the sensor at a predetermined distance or more, and thus it is possible that the problem such as a reduction in a sensing precision due to the influence of the external noise on the information transmission path between the sensor and the personal computer, or the like is caused.

[0020] The present invention has been made in view of the above problems, and it is an object of the present invention to provide a high-precision machinery facility abnormality diagnosis system capable of deciding the presence or absence of an abnormality in a state of normal use without decomposition of a facility like a machinery facility such as a railway vehicle facility, a machine tool, a windmill, or the like, which requires much time and labor to decompose, and thus capable of reducing maintenance/administrative costs and being hardly affected by the noise, and the like.

<Disclosure of the Invention>

[0021] The present invention can be attained by configurations described in the following.

(1) An abnormality diagnosis system for diagnosing a presence or absence of an abnormality of a bearing unit for a railway vehicle axle, comprising:

a sensing/processing portion for outputting a signal generated from the bearing unit as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the bearing unit based on an output of the sensing/processing portion;
a result outputting portion for outputting a decision result of the calculating/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the railway vehicle based on the decision result.

(2) An abnormality diagnosis system according to (1), wherein the calculating/processing portion includes
a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,
an analyzing portion for calculating a predetermined physical quantity in regarding to the bearing unit based on the electric signal distributed from the data accumulating/ distributing portion,
a first data saving portion for saving bearing unit data in regarding to the bearing unit,
a comparing/deciding portion for making the abnormality diagnosis of the bearing unit by comparing/referring an analyzed result of the analyzing portion with the bearing unit data saved in the first data saving portion,
a second data saving portion for saving the analyzed result of the analyzing portion and a decision result of the comparing/deciding portion.

(3) An abnormality diagnosis system according to (2), wherein the analyzing portion includes
a filtering processing portion for removing a noise component of the electric signal fed from the calculating/ processing portion or extracting a particular frequency component to output, and
a frequency analyzing portion for executing a frequency analysis of a signal output from the filtering processing portion, and
the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on a result of the frequency analysis of the frequency analyzing portion.

(4) An abnormality diagnosis system according to (2) or (3), wherein the analyzing portion has a temperature analyzing portion that calculates a temperature of the bearing unit based on the signal output from the data accumulating portion and
the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the temperature calculated by the temperature analyzing portion.

(5) An abnormality diagnosis system according to any one of (2) to (4), wherein the analyzing portion has a rotation

analyzing portion that calculates a rotation speed of the bearing unit based on the signal output from the data accumulating portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the rotation speed calculated by the rotation analyzing portion.

(6) An abnormality diagnosis system according to any one of (1) to (5), wherein the calculating/processing portion outputs data saved in the second data saving portion to the controlling/processing portion in response to the abnormality diagnosis result.

(7) An abnormality diagnosis system according to any one of (1) to (6), wherein the filtering processing portion extracts only a frequency component of 1 kHz or less.

(8) An abnormality diagnosis system according to any one of (1) to (7), wherein a sensing element of the sensing/processing portion is arranged on a stationary portion of the bearing unit in a loading range.

(9) An abnormality diagnosis system according to any one of (1) to (8), wherein the data accumulating/distributing portion does not output the electric signal containing a noise component, which exceeds a predetermined level, to the analyzing portion.

(10) An abnormality diagnosis system according to any one of (1) to (9), wherein the comparing/deciding portion makes the abnormality diagnosis of the bearing unit by comparing levels of a frequency due to the abnormality and its higher harmonics with a reference value.

(11) An abnormality diagnosis system according to any one of (1) to (10), wherein the comparing/deciding portion decides that the abnormality is generated when at least one of peak values of the frequency due to the abnormal and its higher harmonics is larger than a predetermined reference value.

(12) An abnormality diagnosis system according to any one of (1) to (11), wherein the comparing/deciding portion estimates a degree of damage of the bearing unit based on the peak values of the frequency due to the abnormal and its higher harmonics.

(13) An abnormality diagnosis system according to any one of (1) to (12), wherein the comparing/deciding portion makes the abnormality diagnosis by comparing the levels of the frequency due to the abnormal and its higher harmonics.

(14) An abnormality diagnosis system according to any one of (1) to (13), wherein the comparing/deciding portion makes the abnormality diagnosis based on a square mean or a partial overall of a frequency band containing the frequency due to the abnormal.

(15) An abnormality diagnosis system according to any one of (1) to (14), wherein the comparing/deciding portion makes the abnormality diagnosis by applying a cepstrum analysis to a frequency spectrum.

(16) An abnormality diagnosis system according to any one of (1) to (15), wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via a cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, voltage-proof, and electromagnetic noise-resistant properties respectively.

(17) An abnormality diagnosis system according to any one of (1) to (15), wherein a radio communicating device is provided to the sensing/processing portion and the calculating/ processing portion and the calculating/processing portion and the controlling/processing portion respectively, and the signal is transmitted therebetween by using the radio communicating device via radio.

(18) An abnormality diagnosis system according to any one of (1) to (15), wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via the cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, and electromagnetic noise-resistant properties respectively, or the signal is transmitted therebetween by using the radio communicating device.

(19) An abnormality diagnosis system according to any one of (1) to (18), wherein the abnormality diagnosis is made in real time.

(20) An abnormality diagnosis system according to any one of (1) to (18), wherein the abnormality diagnosis is made at a time different from a vehicle traveling time, based on data accumulated in the accumulating portion.

(21) An abnormality diagnosis system according to any one of (1) to (20), wherein the presence or absence of the abnormality of a bearing in the bearing unit and an abnormality occurring location are diagnosed.

(22) An abnormality diagnosis system according to any one of (1) to (20), wherein a flat portion of a wheel is diagnosed.

(23) An abnormality diagnosis system according to any one of (1) to (20), wherein the presence or absence of the abnormality of a gear in the bearing unit and an abnormality occurring location are diagnosed.

(24) An abnormality diagnosis system for a machinery facility having a rotating body, comprising:

a sensor unit having a sensor fitted to a constituent parts of the rotating body to sense a physical quantity of

the rotating body in a rotating operation;
a calculating/processing portion for deciding a presence or absence of an abnormality of the rotating body by analyzing an output signal of the sensor unit and then comparing an analyzed result with predetermined reference data; and
a controlling/processing portion for displaying the analyzed result of the calculating/processing portion and a decision result of the calculating/processing portion, and controlling an operation of the machinery facility in response to the decision result.

(25) An abnormality diagnosis system according to (24), wherein the sensor unit has an output amplifying means for amplifying the output signal of the sensor.
(26) An abnormality diagnosis system according to (24) or (25), wherein the sensor unit has a radio communicating means for transmitting the output signal to the calculating/ processing portion via radio.
(27) An abnormality diagnosis system according to (26), wherein the calculating/processing portion and the controlling/processing portion are provided to a monitoring base station that is remote from the rotating body.
(28) An abnormality diagnosis system according to (27), wherein the sensor unit is fitted to a bearing of a railway vehicle, and
the sensor unit diagnoses the abnormality of the bearing.
(29) A machinery facility abnormality diagnosis system for sensing a presence or absence of an abnormality of a sliding member or a rotating body in a machinery facility, comprising:

a sensor unit having one of plural sensing elements for sensing a signal emitted from the machinery facility; and
a calculating/processing portion for executing a calculating process to decide the presence or absence of the abnormality in the machinery facility based on an output of the sensing element;

wherein the calculating/processing portion is composed of a microcomputer.
(30) A machinery facility abnormality diagnosis system according to (29), wherein the sensor unit is incorporated into the sliding member or the rotating body.
(31) A machinery facility abnormality diagnosis system according to (30), wherein the microcomputer is fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body.
(32) A machinery facility abnormality diagnosis system according to (29), wherein the microcomputer and the sensor unit are mounted on a single device board, and are fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body as a single processing unit.
(33) A machinery facility abnormality diagnosis system according to any one of (29) to (32), wherein the calculating/ processing portion is installed in a single casing.
(34) A machinery facility abnormality diagnosis system according to (33), wherein the sensor unit is arranged integrally in the casing.
(35) A machinery facility abnormality diagnosis system according to any one of (29) to (34), wherein the sensing element senses at least one of temperature, vibration displacement, vibration speed, vibration acceleration, force, distortion, acoustic, acoustic emission, ultrasonic waves, and rotation speed.
(36) A machinery facility abnormality diagnosis system according to any one of (29) to (35), wherein the calculating/ processing portion includes central processing unit, amplifier, analog/digital converter, filter, comparator, pulse counter, timer, interruption controller, ROM, RRAM, digital/analog converter, communication module, and external interface.
(37) A machinery facility abnormality diagnosis system according to any one of (29) to (36), wherein the calculating/ processing portion executes at least one process or more of calculation of feature parameters of a standard deviation and a peak factor, envelope detection, FFT, filtering, wavelet transform, short-time FFT, calculation of a feature frequency due to a defect of the rotating body and comparison/decision.
(38) A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/ allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides the abnormality when a number of times the abnormality is provisionally diagnosed exceeds a threshold value, after a comparison/allocation is executed predetermined

number of times or based on a compared/allocated result obtained every second time period.

(39) A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides a degree of the abnormality according to a number of times the abnormality is provisionally diagnosed, after a comparison/allocation is executed predetermined number of times or based on a compared/allocated result obtained every second time period.

(40) A machinery facility condition monitoring method according to (38) to (39), wherein the signal is A/D-converted into a digital signal, then a process of analyzing a frequency of the digital signal is executed, and then a frequency component generated due to a damage of the machinery facility and calculated based on an operating signal of the machinery facility is compared/allocated with a frequency component derived based on actually measured data every first time period.

(41) A machinery facility condition monitoring method according to (40), wherein the signal is subjected to an amplifying process and a filtering process.

(42) A machinery facility condition monitoring method according to (40) or (41), wherein at least one of the rotating body and the sliding member of the machinery facility is any one of rolling bearing, ball screw, linear guide, and linear ball bearing, and the operating signal of the machinery facility is either a rotation speed signal in the rolling bearing and the ball screw or a moving speed signal in the linear guide and linear ball bearing.

(43) A machinery facility condition monitoring system for a machinery facility having at least one of a rotating body and a sliding member and using the condition monitoring method set forth in (38) or (39), comprising:

at least one sensing/processing portion for sensing a signal generated from the machinery facility;
a calculating/processing portion having a microcomputer that executes a calculating process to decide a condition of the machinery facility based on the signal output from the sensing/processing portion; and
a controlling/processing portion having at least one of a result outputting portion that outputs a decision result of the calculating/processing portion and a controller that feeds back a control signal to a control system of the machinery facility based on the decision result.

(44) A machinery facility condition monitoring system according to (43), wherein at least one of the sensing/processing portion and the microcomputer is installed into the rotating body and the sliding member.

(45) A machinery facility condition monitoring system according to (43) or (44), wherein at least one of the rotating body and the sliding member is a bearing to which a radial load is applied, and

the sensing/processing portion is fixed in a radial load loading range of a bearing housing that is fitted onto a raceway ring of the bearing.

(46) An abnormality diagnosis system for a railway vehicle bearing unit using the machinery facility condition monitoring system set forth in any one of (43) to (45).

(47) An abnormality diagnosis system for a windmill bearing unit using the machinery facility condition monitoring system set forth in any one of (43) to (45).

(48) An abnormality diagnosis system for a machine tool spindle bearing unit using the machinery facility condition monitoring system set forth in any one of (43) to (45).

(49) A machine equipment abnormality diagnosis system comprising:

a sensing/processing portion having a sensor unit that is fixed to a bolt screwed into a housing of the machine equipment and outputs a signal generated from the machine equipment as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the machine equipment based on an output of the sensing/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the machine equipment based on a result of the abnormality diagnosis.

(50) A machine equipment abnormality diagnosis system according to (49), wherein the calculating/processing

portion includes

the calculating/processing portion includes

a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,

an analyzing portion for calculating a predetermined physical quantity in regarding to the machine equipment based on the electric signal distributed from the data accumulating/ distributing portion,

a first data saving portion for saving machine equipment data in regarding to the machine equipment,

a comparing/deciding portion for making the abnormality diagnosis of the machine equipment by comparing the physical quantity calculated by the analyzing portion with the machine equipment data saved in the first data saving portion,

a second data saving portion for saving the analyzed result of the analyzing portion and a result of the abnormality diagnosis of the comparing/deciding portion.

(51) A machine equipment abnormality diagnosis system according to (49) or (50), wherein the calculating/processing portion and the controlling/processing portion are composed of a microcomputer or an IC chip.

(52) A machine equipment abnormality diagnosis system according to any one of (49) to (51), wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion or the calculating/processing portion and the controlling/processing portion without a wire connection.

(53) A bearing unit including an inner ring having an inner ring raceway surface, an outer ring having an outer ring raceway surface, a plurality of rolling elements arranged relatively rotatably between the inner ring raceway surface and the outer ring raceway surface, and a retainer for holding rollably the rolling elements, whereby a bearing to which a radial load is applied is arranged in a bearing housing,

the bearing unit comprising:

an abnormality sensing means provided in a loading range of the bearing housing, for sensing an abnormality from at least one selected from a vibration sensor and a temperature sensor installed/fixed in a single case.

(54) A bearing unit according to (53), wherein a flat portion is provided to a part of an outer peripheral surface of the bearing housing on a loading range side, and the abnormality sensing means is fixed to the flat portion.

(55) A bearing unit according to (54), wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a center portion of a bearing width.

(56) A bearing unit according to (53), wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a width area of the inner ring raceway surface or the outer ring raceway surface.

(57) A bearing unit according to any one of (53) to (56), wherein a case of the abnormality sensing means has a signal carrying means that sends out a sensed signal, and a decision result outputting portion that decides a presence or absence of the abnormality based on the signal sent out via the signal carrying means and output a decision result.

(58) A bearing unit according to any one of (53) to (57), wherein the abnormality sensing means is embedded/fixed on a recess portion formed on the bearing housing, and then secured by molding a clearance between the abnormality sensing means and the recess portion.

(59) A bearing unit according to (58), wherein the abnormality sensing means is fixed to the recess portion via a spacer.

(60) A bearing unit according to any one of (53) to (59), wherein a filtering processing portion for removing an unnecessary frequency band from a vibration waveform from the vibration sensor, an envelope processing portion for detecting an absolute value of a filtered waveform transferred from the filtering processing portion, a frequency analyzing portion for analyzing a frequency of a waveform transferred from the envelope processing portion, a comparing/collating portion for comparing a frequency generated due to a damage calculated based on a rotation speed with a frequency derived based on actually measured data, and a result outputting portion for identifying a presence or absence of the abnormality and an abnormal location based on a compared result in the comparing/collating portion are provided.

<Brief Description of the Drawings>

[0022]

FIG.1 is a view showing a railway vehicle abnormality diagnosis system according to a first embodiment of the present invention;

FIG.2 is a block diagram showing an internal structure of a sensor unit;

FIG.3 is a view showing a data accumulating/distributing portion;
FIG.4 is a table showing relational expressions indicating relationships between defects of respective members of a bearing and abnormal vibration frequencies generated in respective members;
FIG.5 is a view showing a relationship between a loading range and a non-loading range in the bearing;
FIG.6 is a view showing a time-variant waveform of an oscillating signal sensed from the bearing in the first embodiment;
FIG.7 is a view showing a frequency spectrum of the vibration signal sensed from the bearing in the first embodiment;
FIG.8 is a view showing a frequency spectrum of the vibration signal sensed from the bearing in the first embodiment after an enveloping process;
FIG.9 is a flowchart showing a process flow in a first method;
FIG.10 is a graph showing a frequency spectrum when no abnormality is generated;
FIG.11 is a graph showing a frequency spectrum when the abnormality is generated in an outer ring;
FIG.12 is a graph showing a relationship between the frequency spectrum and a reference value when a retainer has a flaw;
FIG.13 is a flowchart showing a process flow in a second method;
FIG.14 is a view explaining the second method;
FIG.15 is a flowchart showing a process flow in a third method;
FIG.16 is a view showing a frequency spectrum when an outer ring has the flaw;
FIG. 17 is a view explaining a fourth method;
FIG.18 is a graph showing a relationship between a size of flaking and a level difference between peaks appearing on the actually measured frequency spectrum data and a reference level;
FIG. 19 is a flowchart showing a process flow in a fifth method;
FIG.20 is a view showing frequency spectrum levels and a reference line;
FIG.21 is a flowchart showing a process flow in a sixth method;
FIG.22 is a graph showing a frequency spectrum when the abnormality is generated in the outer ring;
FIG.23 is a graph showing a frequency spectrum when no abnormality is generated in the outer ring;
FIG.24 is another graph showing a frequency spectrum when the abnormality is generated in the outer ring;
FIG.25 is another graph showing a frequency spectrum when no abnormality is generated in the outer ring;
FIG.26 is a block diagram showing an internal configuration of a sensor unit in a railway vehicle abnormality diagnosis system according to a second embodiment of the present invention;
FIG.27 is a view showing the railway vehicle abnormality diagnosis system according to the second embodiment of the present invention;
FIG.28 is a block diagram showing a schematic configuration of a rotating body abnormality diagnosis system according to a third embodiment of the present invention;
FIG.29 is a block diagram showing a schematic configuration of a rotating body abnormality diagnosis system according to a fourth embodiment of the present invention;
FIG.30 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a fifth embodiment of the present invention;
FIG.31 is a block diagram showing a schematic configuration of a microcomputer shown in FIG.30;
FIG.32 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a sixth embodiment of the present invention;
FIG.33 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a seventh embodiment of the present invention;
FIG.34(a) is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to an eighth embodiment of the present invention;
FIG.34(b) is a side view showing a bearing fitting state in FIG.34(a);
FIG.35(a) is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a ninth embodiment of the present invention;
FIG.35(b) is a side view showing a bearing fitting state in FIG.35(a);
FIG.36 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a tenth embodiment of the present invention;
FIG.37 is a sectional view showing a machinery facility to which a condition monitoring system according to an eleventh embodiment of the present invention is applied;
FIG.38 is a schematic view showing the condition monitoring system according to the eleventh embodiment;
FIG.39 is a block diagram of a calculating/processing portion in FIG.38;
FIG.40 is a flowchart showing procedures of a diagnosis process in a condition monitoring method;
FIG.41 is a view showing a bearing housing of a railway vehicle bearing unit serving as a machinery facility to

which an abnormality diagnosis system according to a twelfth embodiment of the present invention is applied;
FIG.42 is a view showing a railway vehicle abnormality diagnosis system in the twelfth embodiment;
FIG.43 is a view showing a variation of the abnormality diagnosis system according to the twelfth embodiment of the present invention;
FIG.44 is a view showing another variation of the abnormality diagnosis system according to the twelfth embodiment of the present invention;
FIG.45 is a schematic view showing a bearing unit according to a thirteenth embodiment of the present invention;
FIG.46 is a signal processing system diagram in an abnormality sensing means in the bearing unit shown in FIG.45;
FIG.47 is a signal processing system diagram using a method different from FIG.46;
FIG.48 is a sectional view showing a bearing unit according to a fourteenth embodiment of the present invention;
FIG.49 is a sectional view showing a bearing unit according to a fifteenth embodiment of the present invention;
FIG.50 is a sectional view showing a bearing unit in the prior art;
FIG.51 is a sectional view showing another bearing unit in the prior art;
FIG.52 is a sectional view showing still another bearing unit in the prior art;
FIG.53 is a block diagram showing another configurative example in the prior art;
FIG.54 is a block diagram showing still another configurative example in the prior art; and
FIG.55 is a block diagram showing yet still another configurative example in the prior art.

<Best Mode for Carrying Out the Invention>

[0023] A machinery facility condition monitoring method and system and an abnormality diagnosis system according to the present invention will be explained in detail with reference to the accompanying drawings hereinafter.

<First Embodiment>

[0024] FIG.1 shows a railway vehicle abnormality diagnosis system according to a first embodiment of the present invention. An abnormality diagnosis system 1 includes a sensing/processing portion 20 having sensor units 22 each provided to each row of a rolling bearing 21 to output a condition of each row as an electric signal, a calculating/processing portion 30 for calculating/processing the electric signals output from the sensor units 22 to decide the condition such as defect, abnormality, or the like of a railway vehicle facility 10, and a controlling/processing portion 40 for controlling and outputting the decided result of the calculating/processing portion 30.

[0025] The abnormality diagnosis system 1 senses the generation of the abnormality due to the wear or the failure of a plurality of rolling bearings 21 in the bearing unit that bears the axle of the railway vehicle. Each rolling bearing 21 has an outer ring 23 as a stationary portion that is fitted into the vehicle body side, an inner ring 24 fitted onto the axle and rotated together with the axle, and rolling elements 25 such as balls, rollers, or the like held between an outer ring raceway formed on the inner peripheral surface side of the outer ring 23 and an inner ring raceway formed on the peripheral surface side of the inner ring 24 by a retainer (not shown) and arranged reliably between both raceways. Also, the sensor unit is secured to the outer ring 23 of each rolling bearing 21. In FIG.1, the sensing/ processing portion 20 is constructed by sensing portions 20a, 20b, 20c each consisting of the sensor unit 22 secured to each rolling bearing 21.

[0026] The sensor unit 22 has sensors as a plurality of sensing elements that sense various information generated from the machinery facility during the running, e.g., sound J1, temperature J2, vibration (vibration displacement, vibration speed, vibration acceleration) J3, rotation speed J4, distortion J5 generated on the outer ring of the bearing, AE (acoustic emission), moving speed, force, ultrasonic wave, etc., as physical quantities that are changed in response to a rotating condition of the bearing 21. Each sensor outputs the sensed physical quantity to the calculating/processing portion 30 as the electric signal.

[0027] Here, since the calculating/processing portion 30 can distribute/process appropriately the electric signals every sensed information, respective sensing elements are arranged independently in different locations respectively. Thus, a plurality of sensing elements for sensing independently the particular signals such as sound, temperature, vibration, rotation speed, distortion, AE, moving speed, force, ultrasonic wave, and others may be employed in combination. Alternately, a composite sensor unit constructed by installing a plurality of sensing elements into an inside of a housing to sense simultaneously plural types of signals may be employed as the sensor unit 22, in place of independent arrangement of a plurality of sensing elements. Also, a multidirectional simultaneous vibration sensor for sensing the vibration in the multiple directions by one sensor may be employed as the vibration sensor.

[0028] In addition, in order to execute the sensing at a high SN ratio, the signal can be sensed with good sensitivity by fitting the sensor unit 22, especially a vibration sensing element 22d (see FIG.2(a)), to a portion to which a load is applied (loading range) and thus the higher-precision measurement can be attained. Where the "loading range" denotes an area in which the load is applied to the rolling elements, as shown in FIG.5. In the case where the sensor unit is

fitted inevitably to a non-loading range when the space used to fit the sensor is absent in the loading range, a high-tension cable that generates noises is provided to the loading range, or the like, the measurement can be carried out by enhancing a signal sensing sensitivity by virtue of a filtering process executed by a filtering processing portion 34 described later, or the like.

[0029] In the present embodiment, as shown in FIG.2(a), the sensor unit 22 has such a structure that various sensing elements 22b, 22c, and 22d are installed into a unit case 22a. Then, explanation will be made hereunder under the assumption that the temperature sending element 22b for sensing the temperature of the bearing 21, the rotation sensing element 22c for sensing the rotation speed of the inner ring (axle) of the bearing 21, and the vibration sensing element 22d for sensing the vibration generated in the bearing 21 are provided in the unit case 22a.

[0030] Respective sensing elements 22b to 22c amplify the electric signals corresponding to the sensed vibration, temperature, and rotation speed via an amplifier 50 as an output amplifying means, and then output the signals to the calculating/processing portion 30. The amplifier 50 may be provided in the unit case 22a of the sensor respectively as shown in FIG.2(b), or the amplifier 50 may be provided between the sensor unit 22 and the calculating/processing portion 30 respectively as shown in FIG.1, or the amplifier 50 may be provided to an interior of the calculating/processing portion 30. It is preferable that amplifiers 22e, 22f, and 22g should be provided to the sensing elements 22b, 22c, and 22d in the unit case 22a respectively. There is such a possibility that the noise is superposed on the signal during when the signal output from the sensor unit 22 is being transmitted to the calculating/processing portion 30 via the cable, and thus the reliability of measurement is lowered. In this event, if a signal level is amplified in advance via the amplifier 50, the signal is hard to accept the influence of the noise and thus the reliability can be improved.

[0031] The signal is transmitted between the sensor unit 22 and the calculating/processing portion 30 via the cable. In order to improve a measuring precision such as reduction of noise, etc., it is preferable that the cable should have waterproof, oil-resistant, dustproof, rust-preventive, moisture-proof, heat-resistant, and electromagnetic noise-resistant properties. Similarly, in order to improve a measuring precision such as reduction of noise, etc., it is preferable that respective sensing elements 22b to 22d in the sensor unit 22 should have waterproof, oil-resistant, dustproof, rust-preventive, moisture-proof, heat-resistant, and electromagnetic noise-resistant properties. For example, if all sensing elements are incorporated into the sensor unit and then the waterproof, oil-resistant, dustproof, rust- preventive, moisture-proof, heat-resistant, and electromagnetic noise-resistant properties are provided to the unit case 22a of the sensor unit 22, these properties can be embodied.

[0032] The calculating/processing portion 30 is a unit that executes the calculating process of the electric signals as the outputs that are received from respective sensing elements (the temperature sensing element 22b, the rotation sensing element 22c, and the vibration sensing element 22d in the present embodiment) in the sensor unit 22, and then identifies the presence or absence of the abnormality of the bearing and an abnormality occurring location by comparing the analyzed result analyzed by the calculating process and the reference data. Here, the reference data denote reference values of various physical quantities that are sensed by respective sensing elements in the normal condition of the bearing 21 serving as the diagnosed object. More particularly, the reference data contain the information about a frequency component generated by the wear or the failure of the particular portion of the bearing 21, and the like, in addition to the information of the normal bearing 21 about sound, temperature, vibration, rotation speed, distortion, AE, moving speed, force, ultrasonic wave, and the like.

[0033] For instance, the calculating/processing portion 30 may be constructed by using the personal computer or the general- purpose computer into which the existing operating system and the software applications used to execute the abnormality diagnosis. Otherwise, the calculating/processing portion 30 may be constructed as an arithmetic unit that are composed of processing and saving circuits provided independently to respective portions.

[0034] The calculating/processing portion 30 includes a data accumulating/distributing portion 31, a temperature analyzing portion 32, a rotation analyzing portion 33, the filtering processing portion 34, a vibration analyzing portion 35, a comparing/deciding portion 36, an internal data saving portion 37 serving as a first data saving portion, a data accumulating/outputting portion 38 serving as a second data saving portion. Then, configurations and functions of respective portions of the calculating/processing portion 30 will be explained in detail hereunder.

[0035] FIG.3 is a view showing the data accumulating/ distributing portion 31 serving as a first data accumulating portion. The data accumulating/distributing portion 31 has a data accumulating portion 31a, a sampling portion 31b, and a sampling reference setting portion 31c. The data accumulating portion 31a is a data saving medium that save the output signals from the sensing elements 22b to 22d every signal, and can be constructed by various memories, the hard disk, and the like.

[0036] The data accumulating portion 31a receives the signals sent out from the sensing elements 22b to 22d, and then stores temporarily such signals and also allocates such signals to any of the analyzing portions 32, 33, 34 in response to the type of signal. Various signals are A/D-converted into digital signals by an A/D converter (not shown) at the preceding stage to the data accumulating/distributing portion 31. In this event, the A/D conversion and the amplification may be applied in reverse order.

[0037] The sampling reference setting portion 31b sets the reference values that are used to exclude areas, in which

the influence of the noise appears largely, from the analog signal being output from the vibration sensing element 22d, based on the information derived from an external inputting portion 100. Here, the inputting portion 100 is an inputting means such as a mouse, a keyboard, or the like, and the user can set arbitrarily the reference values via the inputting portion 100.

[0038] The sampling portion 31c cuts out vibration, temperature, and rotation speed data serving as the time-variant data into a predetermined length data, and then executes the sampling to output the signal to the analyzing portions in the subsequent stage. When the output signal from the vibration sensing element 22d contains the larger noise than the reference value being set by the sampling reference setting portion 31b, the sampling portion 31c does not execute the sampling of the signal in a period of time containing such noise not to output the signal to the filtering processing portion 34. More particularly, the sampling portion 31c detects two points A and B at which the signal level exceeds a certain predetermined value, and then controls not to output the data to the filtering processing portion 34 and the vibration analyzing portion 35 in a time interval A to B. Accordingly, it is possible not to execute the frequency analysis within the time interval that contains the data on which the large noise is superposed, so that a possibility of executing the false abnormality diagnosis can be reduced. In this case, the sampling reference setting portion 31b and the sampling portion 31c are not always provided. Also, if the similar effect can be achieved, these portions may be arranged in another location, e.g., the preceding stage of the data accumulating portion 31a, or the like.

[0039] The temperature analyzing portion 32 calculates the temperature of the bearing based on the output signal fed from the temperature sensing element 22b, and then sends out the calculated temperature to the comparing/deciding portion 36. The temperature analyzing portion 32 has a temperature transformation table responding to characteristics of the sensing elements, for example, and calculates the temperature data based on a level of the sensed signal.

[0040] The rotation analyzing portion 33 calculates the rotation speed of the inner ring 24, i.e., the axle based on the output signal fed from the rotation sensing element 22c, and then sends out the calculated rotation speed to the comparing/deciding portion 36. For example, when the rotation sensing element 22c is composed of an encoder fitted to the inner ring 24, a magnet fitted to the outer ring 23, and a magnetism sensing element, a signal output from the rotation sensing element 22c is given as a pulse signal that responds to a shape of the encoder and the rotation speed. The rotation analyzing portion 33 contains a predetermined transformation function or transformation table in response to the shape of the encoder, and calculates the rotation speed of the inner ring 24 and the axle from the pulse signal based on the function or the table.

[0041] The vibration analyzing portion 35 executes the frequency analysis of the vibration generated in the bearing 21 based on the output signal from the vibration sensing element 22d. More specifically, the vibration analyzing portion 35 is composed of an FFT computing portion that calculates the frequency spectrum of the vibration signal and calculates the frequency spectrum of the vibration in compliance with the FFT algorithm. The calculated frequency spectrum is fed to the comparing/ deciding portion 36. Also, the vibration analyzing portion 35 may be constructed to execute the enveloping process as the preprocessing prior to the FFT to calculate the envelope of the vibration signal and thus attain a reduction of the noise. The vibration analyzing portion 35 also outputs the envelope data obtained after the enveloping process to the comparing/deciding portion 36, as the case may be.

[0042] Normally the abnormal frequency bands of the vibration caused due to the rotation of the bearing are decided depending upon a size of the bearing, the number of rolling elements, etc. Respective relationships between the defect of respective members of the bearing and the abnormal vibration frequencies generated in respective members are given as shown in FIG.4. In the frequency analysis, the maximum frequency that permits the Fourier transform (Nyquist frequency) is decided in response to a sampling time, and thus preferably the frequency that is in excess of the Nyquist frequency should not be contained in the vibration signal. Therefore, the present embodiment is constructed such that the filtering processing portion 34 is provided between the data accumulating/distributing portion 31 and the vibration analyzing portion 35, a predetermined frequency band is cut out from the vibration signal by the filtering processing portion 34, and the vibration signal containing only the cut-out frequency band is sent out to the vibration analyzing portion 35. When the axle is being rotated at a low speed in the railway vehicle, only the frequency component of 1 kHz or less, for example, may be extracted.

[0043] Also, the filtering processing portion 34 may be arranged in such a manner that the portion first causes the vibration analyzing portion 35 to calculate the frequency spectrum without the filtering process, then estimates previously the frequency band in which the peak will be observed, and then executes the filtering process in answer to the frequency band to execute newly the frequency analysis. With this arrangement, the unnecessary noise can be eliminated effectively and thus the high-precision frequency analysis can be executed.

[0044] FIG.6 is a view showing a time-variant waveform of an oscillating signal as the vibration information J3 in regarding to the vibration of the rolling bearing 21 sensed by the sensor unit 22 in the present embodiment, FIG.7 shows the frequency spectrum of the vibration signal sensed by the vibration analyzing portion 35 in the present embodiment, and FIG.8 shows the frequency spectrum of the vibration signal sensed by the vibration analyzing portion 35 in the present embodiment after the enveloping process.

[0045] In this manner, the vibration analyzing portion 35 applies the frequency analysis to the vibration signal and calculates the frequency spectrum shown in FIG.7 or FIG.8. The strong spectrum is observed at a predetermined frequency period from FIG.8. It is understood from the relational expression given in FIG.4 that this corresponds to a frequency component generated due to the damage of the outer ring 23 of the rolling bearing 21.

[0046] In FIG.3, the temperature analyzing portion 32, the rotation analyzing portion 33, and the vibration analyzing portion 35 are illustrated. But respective analyzing portions may be provided in response to the information that are sensed by respective sensing elements in the sensor unit 22.

[0047] The comparing/deciding portion 36 compares the frequency spectrum of the vibration sensed by the vibration analyzing portion 35 with the reference value saved in the internal data saving portion 37 or the reference value calculated from the frequency spectrum to decide whether or not the abnormal vibration is being generated. Where the reference values are the data of the frequency components generated due to the wear or the failure of the particular location of the bearing or predetermined values contained in the spectrum calculated every frequency spectrum. In order to expect an accuracy of the decision, the comparing/deciding portion 36 refers to the analyzed result of the temperature and the rotation speed obtained by the temperature analyzing portion 32 and the rotation analyzing portion 33 and specification data of various data of the bearing accumulated in the internal data saving portion 37, etc., simultaneously with the decision based on the comparison between the frequency components.

[0048] More particularly, if it is decided based on the frequency spectrum of the vibration that the abnormality occurs, the comparing/deciding portion 36 checks the temperature of the bearing and then decides that the serious abnormality is being generated if the temperature exceeds a predetermined value. Also, if only any one indicates the abnormality, the comparing/ deciding portion 36 decides that any abnormality occurs. Then, if both results are normal, the comparing/ deciding portion 36 decides that no abnormality occurs. If only any one indicates the abnormality, it may be decided that the abnormality occurs when the results are not varied after the decision is made in plural number of times. The comparing/deciding portion 36 outputs the result of the abnormality diagnosis to the data accumulating/outputting portion 38.

[0049] As the particular abnormality diagnosis process executed by the comparing/deciding portion 36 based on the vibration information, following methods will be listed.

(1) Method of using root-means-square values of the envelope data as the reference value

[0050] The present method calculates the frequency components generated at the time of abnormality based on the expressions in FIG.4. Then, the root-means-square values of the envelope data are calculated and then the reference values used in the comparison are calculated from the root-means-square values. Then, the frequencies that are in excess of the reference values are calculated and then compared with the frequency components generated at the time of abnormality. Then, explanation will be made with reference to FIG.9 hereunder.

[0051] First, the vibration of the bearing is sensed by the vibration sensing element 22d installed in the sensor unit 22a (step S101). The sensed signal is amplified by a predetermined amplification factor and then converted into the digital signal by an A/D converter (step S102). The vibration signal converted into the digital signal is saved in the data accumulating/ distributing portion 31 in a predetermined format (step S103).

[0052] Then, the frequency spectrum of the digital signal is calculated (step S104). Then, the filtering processing portion 34 selects a filter bandwidth that is applied to the digital signal, based on the calculated frequency spectrum (step S105). Then, the filtering processing portion 34 executes the filtering process to remove the frequency components other than the selected filter band (step S106), and then outputs the digital signal after the filtering process to the vibration analyzing portion 35. Then, the vibration analyzing portion 35 applies the enveloping process to the digital signal after the filtering process (step S107). Then, the frequency spectrum of the digital signal after the enveloping process is calculated (step S108).

[0053] At the same time, the root-means-square value of the digital signal after the enveloping process is calculated (step S109). Then, the reference value used in the abnormality diagnosis is calculated based on the root-means-square value (step S112). Where the root-means-square value is calculated as a square root of a square mean of the frequency spectrum after the enveloping process. The reference value is calculated as follows based on the root-means-square value in accordance with an Equation (1) or (2).

$$(\text{Reference value}) = (\text{Root-means-square value}) + \alpha \quad (1)$$

$$(\text{Reference value}) = (\text{Root-means-square value}) \times \beta \quad (2)$$

α, β: predetermined value variable according to the type of data

[0054] Then, frequencies generated due to the abnormality of the bearing are calculated based on a table shown in FIG.4 (step S110). Then, levels of abnormal frequency components of respective members corresponding to the calculated frequencies, i.e., an inner ring flaw component Si (Zfi), an outer ring flaw component So (Zfc), a rolling element flaw component Sb (2fb), and a retainer component Sc (fc) are extracted (step S111). Then, respective components Si, So, Sb, Sc are compared with the reference value calculated in step S112 (step S113). Then, if all component values are smaller than the reference value, it is decided that no abnormality is generated in the bearing (step S114). In contrast, if any component exceeds the reference value, it is decided that the abnormality is generated in the concerned location (step S115).

[0055] FIG.10 is a graph showing the frequency spectrum when no abnormality is generated, and FIG.11 is a graph showing the frequency spectrum when the abnormality is generated in the outer ring. In an example in FIG.10, the reference value was derived as -29.3 dB from the envelope data. If the inner ring flaw component Si(Zfi), the outer ring flaw component So (Zfc), the rolling element flaw component Sb (2fb), and the retainer component Sc (fc) are compared with a line of the reference value depicted in FIG.10, the levels of all components are smaller than the reference value. As a result, it is decided that this bearing is normal. In contrast, in the case in FIG.11, since the outer ring flaw component So (Zfc) is protruded largely from the reference value, it can be decided that the abnormality is generated in the outer ring of the bearing.

[0056] Also, FIG.12 is a graph showing a relationship between the frequency spectrum and the reference value when the retainer has the flaw. In FIG.12, a peak that is larger than the reference value is observed at a frequency fo corresponding to the flaw of the retainer. In this manner, since the presence or the absence of the peak of the generated frequency can be decided by the comparison between levels in the frequencies due to the bearing and the reference value, even a small peak shown in FIG. 12 can be diagnosed appropriately.

[0057] Here, the root-mean-square value is employed, but either a mean value such as the running means, or the like or a peak factor (=peak level/mean value) may be employed.

(2) Method of calculating a peak of the spectrum and then comparing a peak frequency and an abnormal frequency

[0058] The present method calculates the frequency components generated at the time of abnormality based on the expressions in FIG.4. Then, it is collated whether or not the peaks, which exceed a predetermined occurring number of times or exceeds the reference value, among the frequency spectrum calculated by the comparing/deciding portion 36 correspond to the frequency components at which the abnormality occurs. Then, explanation will be made in detail with reference to a flowchart shown in FIG.13 hereunder.

[0059] Since the process flows up to step S108 are similar to those set forth in the method (1), their explanation will be omitted herein. In the present method, first the peak value of the resultant frequency spectrum is calculated (step S109). Here, in order to derive the peak of the frequency, at first difference data indicating a difference between a level of a data point in each frequency component and a level of a preceding data point in each frequency component is calculated. Then, an inflection point at which a sign of the difference data is changed from plus to minus is found out, and then it is decided that the peak value appears at the frequency values in regarding to the difference data that give positive/negative criterions. In this case, only the frequency spectrum a ridge (inclination) of which shows a steep and sharp peak is selected as the object of the peak values that are necessary for the diagnosis. For this reason, only when a gradient is larger or smaller than a predetermined reference value (e.g., 1 or -1), it is decided that the frequency spectrum gives the peak.

[0060] FIG.14 is a view showing the frequency spectrum. In FIG.14, a point B out of three successive points A (X_0, Y_0), B (X_1,Y_1), C (X_2,Y_2) gives the peak. In this case, since difference data δ_1 between A and B is given as $\delta_1=Y_1-Y_0>0$ and the difference data δ_2 between B and C is given as $\delta_2=Y_2-Y_1<0$, the difference data is changed from positive to negative. Then, if a gradient $(Y_1-Y_0)/(X_1-X_0)>1$ or a gradient $(Y_2-Y_1)/(X_2-X_1)<-1$ is satisfied here, it is decided that the point B gives the peak.

[0061] Then, the abnormal frequency is calculated from the specification of the bearing based on FIG.4 (step S202). Then, the levels of the abnormal frequency components of respective members corresponding to the calculated frequency, i.e., the inner ring flaw component Si (Zfi), the outer ring flaw component So (Zfc), the rolling element flaw component Sb (2fb), and the retainer component Sc (fc) are extracted (step S203). Then, it is decided by comparing the peak frequency with the frequencies generated at the time of abnormality whether or not the peak frequency agrees with the calculated abnormal frequency (step S204). Then, if a certain peak corresponds to the abnormal frequency, it is decided that the abnormality is generated in the member that corresponds to the concerned abnormal frequency (step S206). In contrast, if the peak corresponds to no frequency, it is decided that no abnormality is generated (step S205).

(3) Method of using a fundamental frequency and a particular harmonic

[0062] The present method compares peak frequencies of a primary value as a fundamental frequency of the abnormal frequency component, a secondary value having a twice frequency of the fundamental frequency, and a quaternary value having a quadruple frequency of the fundamental frequency with the frequencies generated at the time of abnormality respectively, and then decides finally that the abnormality is generated if it is decided that the abnormality is generated at at least two frequencies, or decides that no abnormality is generated if the frequency at which it is decided that the abnormality is generated is one or less. Then, explanation will be made in detail with reference to FIG. 15 hereunder.

[0063] The process flow required until the frequency spectrum is calculated and the frequencies generated due to the abnormality are calculated is similar to the process flow in the method (1). In the present method, as shown in FIG. 15, first it is decided in the comparison whether or not the spectrum value exceeds the reference value at the frequency of the fundamental component (primary component) generated at the time of abnormality (step S301). If the spectrum value exceeds the reference value, it is decided that the primary components coincide with each other. Then, the process goes to step S302. In contrast, if the primary components do not coincide with each other, the process goes to step S311.

[0064] In step S302, it is decided whether or not the spectrum value exceeds the reference value at the frequency of the secondary component that has the twice frequency of the fundamental component generated at the time of abnormality. If the spectrum value exceeds the reference value, it is decided that the secondary components coincide with each other. Then, in step S322, it is decided finally that the abnormality is generated in the concerned location. In contrast, in S302, if the secondary components do not coincide with each other, the process goes to step S312.

[0065] Also, in step S311, it is decided whether or not the spectrum value exceeds the reference value at the frequency of the secondary component that has the twice frequency of the fundamental component generated at the time of abnormality. If the spectrum value exceeds the reference value, it is decided that the secondary components coincide with each other. Then, the process goes to step S312. In contrast, if the secondary components do not coincide with each other, the process goes to step S321, wherein it is decided finally that the abnormality is not generated in the concerned location.

[0066] In step S312, it is decided whether or not the spectrum value exceeds the reference value at the frequency of the quaternary component that has the quadruple frequency of the fundamental component generated at the time of abnormality. If the spectrum value exceeds the reference value, it is decided that the quaternary components coincide with each other. Then, in step S321, it is decided finally that the abnormality is generated in the concerned location. In contrast, if the quaternary components do not coincide with each other, it is decided finally that the abnormality is not generated in the concerned location.

[0067] FIG. 16 is a view showing the frequency spectrum when the outer ring has the flaw. It is understood that harmonics that are the natural-number multiple of Zfc as the fundamental frequency are observed. It is appreciated that, if the reference value is -10 dB in this case, the spectrum value exceeds the reference value at all the primary, secondary, and quaternary components. Therefore, according to the process in the present method, it is decided that the abnormality is generated in the outer ring.

[0068] Normally, such a situation may be considered that a large peak generated accidentally due to the influence of the noise, or the like is observed at the frequencies corresponding to the abnormality. According to the process in the present method, if the peak value does not exceed the reference value at at least two frequencies out of the primary, secondary, and quaternary components, it is not decided that the abnormality is generated. Thus, it is possible to reduce a possibility of misjudgment.

[0069] In the flowchart shown in FIG.15, the comparison is made in order of the primary, secondary, and quaternary components. But the comparison is made in order of the larger peak level. In this case, if the largest peak is smaller than the reference value, it can be decided at that time that no abnormality is generated, and thus a calculation time can be shortened. Also, a combination of the primary value, the secondary value, and the tertiary value or a combination of the secondary value, the quaternary value, and the sexenary value may be used as the combination of frequency components.

(4) Method conducting an abnormality diagnosis and estimating a degree of the damage

[0070] In the methods (1) to (3), the presence or absence of the abnormality is diagnosed. But a size of the damage can be estimated as follows. FIG.17 is a view showing the frequency spectrum after the enveloping process. In FIG. 17, the large peak is observed at the frequency Zfc, and thus it is understood that the damage is generated in the outer ring. A size of the damage generated in the outer ring in which the abnormality occurs can be estimated by comparing a peak value Ln at this Zfc and a reference level L_0 as a mean value of the overall frequency spectrum.

[0071] FIG.18 shows a relationship between a size of flaking and a level difference between peaks appearing on the

actually measured frequency spectrum data d1 and the reference level when the flaking as the damage of the raceway ring is generated in the rolling bearing. In this manner, normally the level difference is increased in proportion to a size of the damage. Therefore, conversely the size of the damage can be estimated if the level difference between the peak on the actually measured frequency spectrum data d1 and the reference level is sensed. In this event, an increase of the peak level on the actually measured frequency spectrum data d1 becomes most conspicuous at the peak that corresponds to the primary value of the frequency components. Therefore, when the abnormality is sensed, an extent of the damage can be estimated by calculating a level difference I between a primary value Ln of the harmonic components and a reference level L_0. Thus, an exchange timing of the damaged parts can be decided in response to the extent of the damage. As a result, exchange of the parts can be carried out at an appropriate timing without the excessive exchange of parts or maintenance, and thus an upkeep cost can be reduced.

(5) Method of using a level difference of a natural-number multiple harmonic component of the fundamental frequency as a reference value

[0072] The present method counts the number of times 2, 3, 4,..., n-degree levels having 2, 3, 4,..., n-tuple frequencies of the fundamental frequency respectively exceed the reference value of the primary level as the fundamental frequency of the abnormal frequency components, and then decides that the abnormality is generated when these 2, 3, 4,..., n-degree levels exceed the reference value in a predetermined number or more. More particularly, the counting is carried out when the n-degree value is {(primary level)-(n-1-)·a} (dB) or more with respect to the primary level. Where a is an arbitrary value. Then, explanation will be made with reference to a flowchart shown in FIG.19 hereunder.

[0073] FIG.19 is a flowchart showing a process flow in the present method. In the present method, the processes required until the frequency spectrum is calculated are identical to the processes in step S101 to step S108 in the flowchart in FIG.9. The processes in step S108 et seq. are shown in FIG.19.

[0074] First, the abnormal frequency due to the abnormality in the bearing is calculated every part (outer ring, inner ring, rolling element, or retainer) of the bearing by referring to the expressions (step S401). Then, the level of the frequency spectrum corresponding to the abnormal frequency is extracted (step S402). Then, levels of the frequency spectra that correspond to the natural-number multiple (2, 3, ..., n-tuple) frequencies of the abnormal frequency are extracted respectively (step S403). Here, assume that secondary, tertiary, quaternary, and quinary components having twice, thrice, quadruple, and quintuple frequencies of the abnormal frequency as the base are extracted.

[0075] Then, the levels of the secondary, tertiary, quaternary, and quinary components are checked on the basis of the primary component as the base (step S404). Here, if the levels of respective components exceed {(primary level)-3(n-1)} (dB), the count indicating that the abnormality is generated is executed. More particularly, the count indicating that the abnormality is generated is executed in respective components in following cases.

(level of the secondary component)>
    (level of the primary component)-3
(level of the tertiary component)>
    (level of the primary component)-6
(level of the quaternary component)>
    (level of the primary component)-9
(level of the quinary component)>
    (level of the primary component)-12

[0076] Then, the final abnormality decision is made by checking whether or not the count number of times indicating that the abnormality is present exceeds the predetermined number of times (step S405). Here, it is decided finally that the abnormality is generated if the count number of times indicating that the abnormality is present exceeds two times, while it is decided finally that no abnormality is generated if the count number of times is once or less.

[0077] FIG.20 is a view showing a relationship between a level of the frequency spectrum and a reference line when the inner ring of the cylindrical roller bearing (outer diameter 215 mm, inner diameter 100 mm, width 47 mm, and number of roller 14) is rotated at about 300 min^{-1}. In FIG.20, a straight line is a criterion line obtained by connecting the above reference values by a line. In the case where the bearing has the flaw, the values of the secondary components or more are in excess of the criterion line, but the peak level of the secondary and quaternary compositions, which correspond to the roller missing sound also generated in the normal condition, fall below this criterion line. Since normally the higher order components of the roller missing sound (rolling element missing sound) are low rather than the case where the outer ring has the flaw, most of the sound values fall below this criterion line, as shown in FIG.20. As a result, even when the peaks of the roller missing sound, or the like appear at the same frequencies as the case where the outer ring has the defect, it is possible to decide whether or not the bearing is abnormal or normal, with good precision by comparing the levels of the higher order components mutually.

(6) Method of using a square mean or a partial overall of a level every frequency band

[0078] The present method executes the abnormality diagnosis by using not the peak level value itself of the frequency caused due to the abnormality but a square mean or a partial overall of the level of the frequency band containing the frequency caused due to the abnormality. Here, the square mean Vi and the partial overall Si are given by following equations. Where V_{RMS} and S_{OA} are the square mean and the partial overall in the full frequency band respectively. The overall denotes a total sum in the particular specified interval.

<Formula 1>

$$Vi = \frac{1}{m}\sum_{k=1}^{m}(P_k - \bar{P}_m)^2 \qquad ...(1)$$

$$Si = \sum_{k=1}^{m} P_k \qquad ...(2)$$

$$V_{RMS} = \frac{1}{N}\sum_{i=1}^{N}(P_i - \bar{P})^2 \qquad ...(3)$$

$$S_{OA} = \sum_{i=1}^{N} P_i \qquad ...(4)$$

where

$$N \cdot \Delta f < \frac{f_s}{2} \qquad (5)$$

m: cut-out frequency bandwidth (number of data)
/Pm: spectrum mean value in the interval m
Pi: spectrum value at the frequency i
/P: spectrum mean value in the interval N
fs: sampling frequency
Δ f: width of neighboring frequencies (frequency resolution)

[0079] FIG.21 is a flowchart showing a process flow in the present method. In the present method, the processes required until the frequency spectrum is calculated are identical to the processes in step S101 to step S108 in the flowchart in FIG.9. The processes in step S108 et seq. are shown in FIG.21.

[0080] First, the abnormal frequency caused due to the abnormality in the bearing is calculated by referring to the expressions shown in FIG.4 every part (outer ring, inner ring, rolling element, or retainer) of the bearing (step S501). Then, the square mean (Vi) or the partial overall (Si) in the frequency band containing the calculated frequency, and a normalized value as the square mean (V_{RMS}) or the partial overall (S_{OA}) of the overall frequency spectrum band are calculated (step S502). Then, a quotient value obtained by dividing the square mean (Vi) or the partial overall (Si) in the primary component bandwidth by the normalized value (V_{RMS} or S_{OA}) or a difference value between them is calculated (step S503).

[0081] Then, it is decided whether or not the quotient value or the difference value is within the normal range, more particularly whether or not the quotient value or the difference value exceeds a predetermined value, by comparing/collating the quotient value or the difference value with the saved reference data (step S504). Then, if the quotient value or the difference value is more than or less than a predetermined reference value, it is decided that the abnormality is generated, and then the abnormality occurring location is identified based on the frequency band (step S505). Here, it may be determined by the actual measurement that the abnormality decision should be made depending on whether the above value is more than the predetermined reference value or is less than the predetermined reference value. Except the above case, it is decided that no abnormality is generated (step S506).

[0082] The above method will be explained by referring to the actual measured result. FIG.22 is a graph showing the frequency spectrum when the abnormality is generated in the outer ring, and FIG.23 is a graph showing the frequency spectrum when no abnormality is generated in the outer ring. The abnormal peak frequency band is present near the left end (around 10 to 20 Hz) of FIG.22. The square mean value Va of the overall spectrum is 0.016. Also, the square mean value Vn of the overall spectrum corresponding to FIG.20 is 0.008. Suppose that the frequency bandwidth extracted with respect to the abnormal frequency band (fundamental frequency) generated due to the flaw of the outer ring is 2 Hz, the value derived by normalizing the square mean value by V in this bandwidth is 90.78 in the case in FIG.22 and is 38.47 in the case in FIG.23. It is understood that, when the abnormality is generated, the normalized value is about 2.4 times larger than that in the normal condition. Therefore, if a predetermined threshold value is provided either between 90.78 and 38.47 or to a ratio between the normal condition and the abnormal condition, it can be decided that the abnormality is generated in the outer ring when the normalized value is larger than the threshold value.

[0083] Meanwhile, FIG.24 and FIG.25 show examples in which plural bands are employed. FIG.24 is a graph showing an envelope frequency spectrum of the machinery facility having the roller bearing, which has the damage in its outer ring, and the normal gear (the number of teeth; 31). In FIG.24, five frequency peaks are observed and also the secondary component to the quinary component are observed in every integral multiple of the fundamental frequency. FIG.25 shows an observed data in the normal condition corresponding to FIG.24, and no singular frequency is found.

[0084] Then, the above approach is also applied to the data in FIG.24 and FIG.25. The value derived by normalizing a sum of the square mean values in respective bands of the fundamental frequency to the quinary component, which are generated due to the flaw of the outer ring, by the square mean value of the overall spectrum is given as 11.64 in the case in FIG.24 and 5.19 in the case in FIG.25. Here, the quinary harmonic means the fifth peak that is counted from the fundamental frequency. It is understood that, when the abnormality is generated, the normalized value is about 2.2 times larger than that in the normal condition. Therefore, if a predetermined threshold value is provided either between 11.64 and 5.19 or to a ratio between the normal condition and the abnormal condition, it can be decided that the abnormality is generated in the outer ring when the normalized value is larger than the threshold value.

[0085] The above processes are the particular processing pattern when the decision to check whether or not the abnormality is caused is made by the comparing/deciding portion 36. The comparing/deciding portion 36 may be constructed to execute the abnormality diagnosis by using plural deciding methods out of these methods. In order to improve an accuracy of the abnormality diagnosis, it is preferable that the abnormality should be decided by using plural deciding methods.

[0086] The data accumulating/outputting portion 38 is a saving portion for saving the decision result of the comparing/deciding portion 36, and is composed of a hard disc, a memory medium, or the like. The data accumulating/outputting portion 38 outputs the decision result to a controlling portion 41 and a result outputting portion 42. The data accumulating/ outputting portion 38 is constructed to output the result to the controlling/processing portion 40 in real time, but is not limited to this. The data accumulating/outputting portion 38 may be constructed to output periodically to the controlling/ processing portion 40, or may be constructed to output the result only when the result is necessary for an operation of the controlling/processing portion 40 (when it is decided that the abnormality occurs), as explained in the following.

[0087] The controlling/processing portion 40 has the result outputting portion 42 as a displaying means for displaying the analyzed result or the decision result of the calculating/ processing portion 30 in a predetermined display mode, and the controlling portion 41 for feeding back a control signal S1 to a control system, which controls an operation of a driving system of the vehicle into which the bearing 21 is incorporated, in response to the decision result of the comparing/deciding portion 36.

[0088] More specifically, the result outputting portion 42 informs of the analyzed result or the decision result of the calculating/processing portion 30 by a monitor, an image display, or a printing output to a printer, and also informs of the result by flashing an alarm lamp or operating an alarm when the decision result of the calculating/processing portion 30 indicates that the abnormality is generated.

[0089] For example, when the decision result of the calculating/ processing portion 30 indicates that the abnormality is generated, the controlling portion 41 feeds a control signal S1 instructing a travel stop of the vehicle, a reduction of the speed, or the like to a travel controller of the vehicle in answer to a degree of the abnormality. In the present

embodiment, a plurality of sensor units 22 sense continuously a condition of the bearing in the bearing unit, and the calculating/processing portion 30 executes the abnormality diagnosis sequentially based on the sensed data. Therefore, the controlling/ processing portion 40 informs immediately of the abnormality when the abnormality occurs, and then performs the control of the vehicle. That is, a flow of sensing, analyzing, deciding and result outputting processes are carried out in real time.

[0090] Now, the sensor unit 22 may be constructed to execute the measurement constantly or may be constructed to execute the measurement every predetermined time. Also, instead of the real-time abnormality diagnosis, only the measurement and the accumulation of measured data may be executed during the traveling of the vehicle and then the analysis may be executed later in another location. For example, only the measurement may be carried out in the daytime and then the analysis, the decision, and the result output may be carried out together with in the nighttime.

[0091] As explained above, the axle bearing unit abnormality diagnosis system 1 in the present embodiment is the abnormality diagnosis system that diagnoses the presence or absence of the abnormality of the bearing unit of the railway vehicle axle bearing unit, and includes the sensing/processing portion 20 having a plurality of sensing elements for outputting the signal generated from the bearing unit as the electric signal, the calculating/processing portion 30 performs the calculating process to execute the abnormality diagnosis of the bearing unit based on the output of the sensing/processing portion 20, the result outputting portion 42 for outputting the decision result from the calculating/ processing portion 30, and the controlling portion 41 for feeding back the control signal to the control system of the railway vehicle based on the decision result.

[0092] Also, in the abnormality diagnosis system 1 in the present embodiment, the outputs of the sensor units 22 incorporated in advance into the bearings 21 are analyzed by respective analyzing portions 32, 33, 35 of the calculating/ processing portion 30 to check whether or not the abnormality is caused due to the wear or the failure of the constituent parts of the bearing 21. Then, the abnormality diagnosis system 1 decides the presence or absence of the abnormality by comparing the analyzed result with the reference data prepared previously in the internal data saving portion 37.

[0093] Accordingly, this abnormality diagnosis system 1 can decide whether or not the abnormality due to the wear or the failure of the constituent parts of the sensor built-in bearing 21 is present. Therefore, the presence or absence of the abnormality can be decided in the normal condition of use not to decompose the sensor built-in bearing 21 itself or the railway vehicle itself containing the bearing 21. As a result, a frequency of overhauling/assembling operations that take a lot of time and labor can be reduced, and thus maintenance/ administrative costs can be reduced.

[0094] Also, the decision is made mechanically based on the analysis and the comparison executed by specified calculating processes. Therefore, the decision is seldom varied owing to a degree of expertise or individual differences of the person in charge of inspection rather than the visual inspection in the prior art, and thus the reliability of the diagnosis to check the presence or absence of the abnormality can be improved.

[0095] Also, the sensor units 22 are installed directly into the outer ring, or the like as the constituent parts of the rotating body constituting the rolling bearing 21, and then the sensors can sense physical quantities generated from the rolling bearing 21 with high sensitivity. Therefore, such a possibility can be reduced that peaks of the frequency components of the sound or the vibration generated by other articles around the rolling bearing 21 exert a harmful influence upon an SN ratio of the signal sensed by the sensor, and thus improvement of analysis/decision precisions can be attained by improving the SN ratio of the output signal of the sensor.

[0096] As a consequence, such a possibility can be eliminated that, for example, the sensed signal of the sensor unit 22 is largely distorted by the peak of the frequency component of the noise generated when the railway vehicle passes over the rail joint, the vibration generated from the devices, and the like regardless of the bearing 21, and the like. Also, reduction of a computing load and reduction of a loss of time required for the analysis can be achieved by improving the SN ratio of the output signal of the sensor unit, and thus improvement of the analysis/decision precisions and the acceleration of the process can be achieved.

[0097] Also, in the present embodiment, since the amplifiers that which amplify the sensor output respectively are built in the sensor unit 22, the output signal of the sensor unit 22 has already been amplified to have the large amplitude. Therefore, the influence of the noise superposed on the signal transmission path between the sensor unit 22 and the calculating/processing portion 30, or the like can be suppressed. As a result, reduction of a process precision due to the noise can be prevented, and thus the reliability of the abnormality diagnosis can be improved.

[0098] In this event, the abnormality diagnosis system 1 in the present embodiment diagnoses the presence or absence of the abnormality of the bearing in the bearing unit and the abnormality occurring location, but the system is not limited to this configuration. The system may be constructed to diagnose the flat portion of the axle, or may be constructed to diagnose the presence or absence of the abnormality of the gear in the bearing unit and the abnormality occurring location. Therefore, various large-size rotating bodies that take a lot of time and labor to remove and fit the parts can be chosen as the object of the abnormality diagnosis in the present invention.

[0099] As above, the approaches (1) to (6) are described as the particular processes of the abnormality diagnosis executed by the comparing/deciding portion 36 based on the vibration information. But the present invention is not limited to the above approaches. The abnormality diagnosis may be executed by analyzing the frequency spectrum

by virtue of the cepstrum analysis.

<Second Embodiment>

[0100] Next, a machinery facility abnormality diagnosis system according to a second embodiment of the present invention will be explained in detail hereunder. In this case, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0101] In the present embodiment, as shown in FIG.27, a sensing/ processing portion 51 consisting of sensing portions 51a, 51b, 51c each having a sensor unit 52 that communicates with the calculating/processing portion 30 via radio is provided in place of the sensing/processing portion 20. The sensing portions 51a, 51b, 51c are constructed by fitting the sensor unit 52 onto the outer ring 23 of the bearing 21 respectively. In the sensor unit 52, a temperature sensing element 52b, a rotation sensing element 52c, a vibration sensing element 52d, and a transmitting portion 52h for radio communication are fitted into an interior of a sensor case 52a. An amplifier for amplifying the signals sensed by the sensing elements 52b to 52d by a predetermined amplification factor may be provided to the sensing element respectively. The transmitting portion 52h transmits the signals to a receiving portion 60 provided in the calculating/ processing portion 30 via radio.

[0102] With the above arrangement, the sensor unit can be fitted to the bearing unit without regard to the wiring between the sensing/processing portion 51 and the calculating/processing portion 30, and the like. Therefore, a margin for arrangement of the sensors is increased and thus it can be facilitated to fit the sensor unit to the position that enhances a sensing precision. The calculating/processing portion 30 and the controlling/processing portion 40 may be connected via radio communication by providing the similar transmitter portion and receiver portion.

[0103] Other configurations and operations are similar to those in the first embodiment.

<Third Embodiment>

[0104] FIG.28 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a third embodiment of the present invention. In a rotating body abnormality diagnosis system 60, the sensor unit installed into the sensor built-in bearing 21 that bears the axle is improved in the abnormality diagnosis system 1 in the first embodiment, and also a installing mode of the calculating/processing portion 30 and the controlling/ processing portion 40, which execute predetermined processes based on the output signal of the sensor unit, are devised.

[0105] The particular configurations of the processing methods of the calculating/processing portion 30 and the controlling/ processing portion 40 are similar to those in the first embodiment. Therefore, the same reference numbers are affixed to the common configurations, and thus explanation of the calculating/processing portion 30 and the controlling/ processing portion 40 will be omitted herein.

[0106] A sensor unit 61 in the present embodiment is similar to the first embodiment in that, as shown in FIG.28, the sound J1, the temperature J2, the vibration J3, the rotation speed J4, the distortion J5, AE, the moving speed, the force, the ultrasonic wave, and others and that these sensed signals are amplified by the amplifier 50 (not shown) to output.

[0107] The sensor unit 60 in the present embodiment has a radio communication device that transmits the output signal fed from the amplifier 50 via radio. An output of the sensor unit 60 is sent out to a signal transmitting/receiving device 63 via radio communication.

[0108] For example, the signal transmitting/receiving device 63 is provided to sides of railway tracks, away stations, etc. at an appropriate interval within an effective range of a radio signal along the traveling route of a railway vehicle 65 on which the sensor built-in bearing 21 is mounted. The signal transmitting/receiving device 63 sends out the signal received from the sensor unit 61 to an information processing center 67 via cable or radio communication.

[0109] The information processing center 67 has the calculating/ processing portion 30 and the controlling/processing portion 40. The information processing center 67 receives the output signals of the sensor units 61 via the signal transmitting/ receiving device 63 and accumulates the signals in the data accumulating/distributing portion 31 in the calculating/ processing portion 30. Then, the data accumulating/ distributing portion 31 distributes the received signals to respective analyzing portions 32, 33, 35 in the calculating/ processing portion 30. Predetermined processes are applied to the distributed signals in respective analyzing portions 32, 33, 35.

[0110] The identification information (ID information) used to identify the sensor unit that outputs the signal are contained in the output of the sensor unit 61. The calculating/ processing portion 30 and the controlling/processing portion 40 decide from which bearing 21 the received output is sent out, based on the identification information to discriminate the data and execute the process and the accumulation every bearing. As a result, the information processing center 67 causes the calculating/processing portion 30 and the controlling/ processing portion 40 to share with a plurality of railway vehicles 65, and thus performs the central management of the abnormality diagnosis of a plurality of bearings 21.

[0111] Also, a radio communication device (not shown) for feeding back a control signal S1 to a control system of the railway vehicle 65 via radio communication is added to the controlling/processing portion 40 provided in the information processing center 67.

[0112] In the above abnormality diagnosis system 60, a margin for arrangement of the calculating/processing portion 30 and the controlling/processing portion 40 can be enhanced rather than the case where the output of the sensor unit 61 is transmitted to the calculating/processing portion via the signal line provided on the railway vehicle having the bearings, and thus the install of the rotating body abnormality diagnosis system 60 can be facilitated.

[0113] Also, since the identification information (ID information) are contained in the signal output from the sensor unit 61, the calculating/processing portion 30 and the controlling/processing portion 40 in the information processing center 67 can be shared with a plurality of railway vehicles 65. Thus, the central management of the abnormality diagnosis of a large number of bearings 21 can be carried out and thus improvement in an efficiency of the abnormality diagnosing process of the bearing 21 and reduction in a cost of the abnormality diagnosing equipment can be attained.

[0114] Other configurations and operations are similar to those in the first embodiment.

<Fourth Embodiment>

[0115] FIG.29 shows a schematic configuration of a machinery facility abnormality diagnosis system according to a fourth embodiment of the present invention. In this case, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0116] In a machinery facility abnormality diagnosis system 70 in the fourth embodiment, the sensor built-in bearing 21 shown in the first embodiment is used as the bearing that bears the axle of the railway vehicle 65, and then the data sensed by the sensor unit 22 incorporated into the bearing 21 are analyzed/decided by a calculating/processing portion 73 and a controlling/processing portion 75 provided in an information processing center 71 that is provided away from the railway vehicle 65.

[0117] In the calculating/processing portion 73, constituent means for analyzing/deciding the signals output from the sensor unit 22 are common to the first embodiment, but the data accumulating/distributing portion 31 for accumulating temporarily the output data from the sensor unit 22 and also distributing the data to the analyzing portions 32, 33, 35 in response to the data type can be detachably attached easily.

[0118] Also, the railway vehicle 65 is equipped with an accumulating portion connector (not shown). The data accumulating/distributing portion 31 attached to this accumulating portion connector can accumulate the signals output by the sensor units 22 in the bearings 21 therein.

[0119] In this abnormality diagnosis system 70, the data accumulating/distributing portion 31 that accumulates the outputs of the sensor units 22 therein is removed from the railway vehicle 65 and then is carried into the information processing center 71 and connected to the calculating/ processing portion 73 in the information processing center 71. Then, various data stored in the data accumulating/distributing portion 31 are analyzed/decided by the calculating/ processing portion 73, and then the result outputting portion 27 in the controlling/processing portion 75 informs the caretaker, or the like of the decision result and the analyzed result in the calculating/processing portion 73.

[0120] After the analysis/decision of the accumulated data are completed, the data accumulating/distributing portion 31 is subjected to the maintenance such as erase of the used data, or the like, as the case may be, and then is returned to the railway vehicle 65 to use again.

[0121] The abnormality diagnosis system 70 having the above configuration is unsuited to the real-time analysis/ decision. But this system is suited to the case where the data accumulated in the data accumulating/distributing portion 31 are kept safe for a long term or are analyzed in detail.

[0122] Also, like the case of the third embodiment, the calculating/processing portion 73 and the controlling/ processing portion 75 provided in the information processing center 71 can be shared with a number of vehicles. Therefore, the abnormality diagnosis system 70 is suited to reduction in the cost of equipment required to execute the abnormality diagnosis.

[0123] Other configurations and operations are similar to those in the first embodiment.

<Fifth Embodiment>

[0124] FIG.30 shows a machinery facility abnormality diagnosis system according to a fifth embodiment of the present invention. In this event, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0125] A machinery facility abnormality diagnosis system 80 in the fifth embodiment detects generation of the abnormality generated due to the wear or the failure of constituent parts of the rolling bearing 21 from the rolling bearing 21 that bears the axle of the railway vehicle. In other words, the rolling bearing 21 that bears the axle corresponds to at least one of the rotating body and the sliding member as the diagnosed object from which the presence or absence

of the abnormality is sensed, and the carriage or the railway vehicle whose axle is supported by the rolling bearings 21 corresponds to a machinery facility 90 that contains one or plural rotating bodies or sliding members.

[0126] In the case of the present embodiment, the bearing 21 is the sensor built-in bearing in which the sensor unit 22 for sensing various physical quantities such as sound, vibration, or the like generated in the rotating operation of the bearing and outputting them as the electric signal is fitted into the outer ring as the constituent parts of the bearing. A plurality of the sensor built-in bearings 21 are used in one vehicle.

[0127] The machinery facility abnormality diagnosis system 80 in the present embodiment includes a plurality of sensor units 22 provided every bearing 21, a microcomputer 81 as the calculating/processing portion that decides the presence or absence of the abnormality in the bearing 21 by analyzing the outputs of the sensor units 22 based on predetermined calculating processes and then comparing the analyzed result with reference data prepared in advance, and the controlling/processing portion 40 for displaying the analyzed result and the decision result of the microcomputer 81 in a predetermined display mode and feeding back the control signal to the control system of the railway vehicle in response to the decision result.

[0128] The physical quantity in the sliding operation (rotating operation) of the bearing 21 as the sliding member is the physical quantity that is changed in response to the rotating condition of the bearing 3. For example, various information such as sound and vibration generated by the bearing 3, rotation speed and temperature, distortion generated on the constituent parts of the sliding member, and the like may be considered.

[0129] Like the first embodiment, the sensor unit 22 includes one or plural sensing elements that sense a lot of information such as sound J1, temperature J2, vibration (vibration displacement, vibration speed, vibration acceleration) J3, rotation speed J4 of the bearing, distortion J5 generated on the outer ring of the bearing, AE, moving speed, force, ultrasonic wave, etc. as the physical quantity that is changed in response to the rotating condition of the bearing 21. Then, the sensor unit 22 sends out these sensed information to the microcomputer (calculating/processing portion) 81 as the sensed signals.

[0130] The sensor unit 22 has such a configuration that various sensors are installed/bold every sensed information in the sensor case 22a secured to the outer ring of the bearing. Also, an output amplifying means for amplifying the output signals of respective sensors to output is built in the sensor case 22a.

[0131] The reference data that are compared with the analyzed result are various physical quantities that are sensed in the normal condition of the bearing 21 as the diagnosed object by the sensor unit. More particularly, there are information such as frequency components generated by the wear and the failure of the particular location of the bearing 3, and the like, in addition to sound information of the normal bearing 21, temperature information of the bearing, vibration information, rotation speed information of the bearing, distortion information generated on the outer ring of the bearing, and others.

[0132] The microcomputer 81 is a one-chip microcomputer or a one-board microcomputer that is developed for the system in the present embodiment. The similar processes to those executed in the inside of the calculating/processing portion 30 are executed in the inside of the microcomputer 81. More specifically, as shown in FIG.31, the microcomputer 81 has the data accumulating/distributing portion 31, the temperature analyzing portion 32, the rotation analyzing portion 33, the filtering processing portion 34, the vibration analyzing portion 35, the comparing/deciding portion 36, and the internal data saving portion 37, and executes the calculating process of the electric signals as the output received from the sensor to identify the presence or absence of the abnormality of the bearing and the abnormality occurring location, as explained in the first embodiment. Then, the microcomputer 81 outputs the abnormality diagnosis result to the controlling/processing portion 40. In the present embodiment, the analyzed result in the analyzing portions 32, 33, 35 and the decision result in the comparing/deciding portion 36 are output directly to the controlling/processing portion 40. But the data accumulating/ outputting portion may be provided, like the first embodiment.

[0133] The controlling/processing portion 40 has the result outputting portion 42 as the displaying means for the analyzed result and the decision result in the microcomputer 81 in a predetermined display mode, and the controlling portion 41 for feeding back the control signal S1 to the control system, which controls an operation of a driving mechanism of the vehicle into which the bearings 21 are incorporated, in response to the decision result of the comparing/deciding portion 36. The operations/effects of the controlling/processing portion are similar to those explained in the first embodiment.

[0134] In the machinery facility abnormality diagnosis system 80 in the present embodiment explained as above, the presence or absence of the abnormality due to the wear and the failure of the constituent parts of the rolling bearing 21 can be decided by analyzing the output of the sensor unit 22, which is incorporated previously into the rolling bearing 21 as the sliding member, by virtue of the microcomputer 81 as the information processing device and then comparing the analyzed result with the reference data prepared previously. Therefore, the abnormality can be decided still in the normal condition of use without overhaul of the rolling bearing 21 itself and the railway vehicle itself.

[0135] As a result, a frequency of the troublesome overhauling/ assembling operations can be reduced and thus the maintenance/ administrative costs can be reduced. Also, since the decision is made mechanically based on the analysis and the comparison executed by specified calculating processes, the decision is hardly varied owing to a degree of

expertise or individual differences of the person in charge of inspection rather than the visual inspection in the prior art, and thus the reliability of the diagnosis to check the presence or absence of the abnormality can be improved.

[0136] Also, the information processing portion is constructed by using the microcomputer 81, and the microcomputer 81 itself can be prepared as a one-chip or one-board small dedicated unit. Therefore, the overall system can be down-sized considerably in comparison with the monitoring system that uses the general- purpose personal computer as the information processing device, and thus an occupied space required for the equipment can be reduced. As a result, the installation of the information processing portion into the machinery facility containing the sliding member (i.e., railway vehicle, or the like) can be facilitated.

[0137] Also, the sensor unit 22 is incorporated directly into the outer ring as the constituent parts constituting the rolling bearing 21, or the like, and thus the sensor unit 22 can sense the physical quantity generated by the rolling bearing 21 with high sensitivity. Therefore, such a possibility can be reduced that the peaks of the frequency components of the sound or the vibration generated by other articles surrounding the rolling bearing 21 exert the harmful influence upon the SN ratio of the signal sensed by the sensor, and thus improvement of the analysis/decision precisions can be attained by improving the SN ratio of the output signal of the sensor.

[0138] In addition, since the information processing portion can be formed in a compact size and also there is no need to use the large general-purpose casing, or the like, an earthquake- proof property as the information processing device can be improved easily. As a result, the information processing portion as well as the sensor unit 22 can be arranged in close vicinity to the rolling bearing 21, and thus the reliability of the abnormality diagnosis can be improved because the rolling bearing 21 and the microcomputer 81 are arranged closely to avoid the influence of the external noise.

[0139] Also, in the present embodiment, an output amplifying means (amplifier) for amplifying the output signal to output is built in the sensor unit itself. In this event, the output amplifying means for amplifying the sensor output may be connected between the sensor unit 22 and the microcomputer 81, or may be built in the microcomputer 81 side.

<Sixth Embodiment>

[0140] FIG.32 is a block diagram showing a schematic configuration of a machinery facility abnormality diagnosis system according to a sixth embodiment of the present invention.

[0141] A machinery facility abnormality diagnosis system 100 in the present embodiment is constructed such that a single microcomputer 81 processes the information of a plurality of sensor units 22. Since remaining configurations are similar to those in the fifth embodiment, the same reference numbers as those in the fifth embodiment are affixed to the common configurations, and thus explanation of the microcomputer 81 and the controlling/processing portion 40 will be omitted herein.

[0142] In case the microcomputer 81 has an enough processing performance in reserve, the single microcomputer 81 is caused to process the information of a plurality of sensor units 22 in this manner. Therefore, the number of equipments of the expensive microcomputer 81 can be reduced and a cost reduction can be attained.

[0143] In the above embodiments, install positions of the microcomputer 81 are not particularly mentioned. It is preferable that the microcomputer 81 as well as the sensor unit 22 should be fitted to the rotating body or the sliding member or the mechanism parts for supporting the sliding member. By doing this, such a system instating mode can be realized that both the sensor unit 22 and the microcomputer 81 are arranged in close vicinity to each other on the same constituent member. Therefore, a length of the signal line between the sensor unit 22 and the microcomputer 81 is not extended, and thus generation of the disadvantages caused by interwining of the signal line, and the like can be prevented.

[0144] Also, the influence of the external noise upon the signal transmission line between the sensor unit 22 and the microcomputer 81 can be reduced, and thus the reliability of the sensed signal can be improved.

<Seventh Embodiment>

[0145] FIG.33 shows a machinery facility abnormality diagnosis system according to a seventh embodiment of the present invention.

[0146] In a machinery facility abnormality diagnosis system 110 in the seventh embodiment, the microcomputer 81 and the sensor unit 22 are mounted on a single device substrate and then fitted to the constituent parts of the rolling bearing 21 as a single processing unit 112. Since the rolling bearing 21 and the controlling/processing portion 40 to which the microcomputer 81 outputs the decision result may have the same configuration as those in the above embodiments, their explanation will be omitted herein. According to the abnormality diagnosis system 110 constructed in this manner, the fitting of the monitoring system to the machinery facility 90 can be completed by fitting the single processing unit 112 thereto, and thus a fitting workability can be improved.

[0147] In the machinery facility abnormality diagnosis system according to the present invention, the sensor unit 22

and the microcomputer 81 are not connected via the signal cable, or the like, and the signal may be transmitted/received via radio communication. When doing this, a margin for arrangement of the microcomputer 81 and the controlling/processing portion can be enhanced rather than the case where the output of the sensor unit 22 is transmitted to the microcomputer 81 via the signal cable that is provided on the equipment containing the sliding member, and thus the installation of the machinery facility abnormality diagnosis system can be further facilitated.

<Eighth Embodiment>

[0148] FIG.34(a) and FIG.34(b) show a machinery facility abnormality diagnosis system according to an eighth embodiment of the present invention.

[0149] In a machinery facility abnormality diagnosis system 151 of the eighth embodiment, a diagnosis unit 161 constructed by mounting a microcomputer containing a CPU 152 to execute the calculating process, an amplifier circuit (Amp) 153, A/D converters (ADCs) 154, 155, external memories (RAM, ROM, ROM) 156, 157, 158, and the communication circuits (LANIF, SCI) 159, 160 on a board (not shown) is installed into a case (casing) 161A. Then, a piezoelectric sensor 162, a temperature sensor 163, and a rotating pulse generator 164 are fitted to the bearing 21 as the sensors.

[0150] The piezoelectric sensor 162 detects a vibration acoustic signal generated when the rolling elements (not shown) of the bearing 21 pass over the flaw on the raceway ring (not shown), an AE (acoustic emission) signal generated when the minute crack is developing, or the like, and converts such signal into a voltage or charge signal. The voltage or charge signal is amplified at about 20 to 40 dB by a pre-amplifier (preamplifier circuit) 165 arranged in close vicinity to the piezoelectric sensor 162. Then, the signal after catered into the case 161 is converted into a voltage signal, a level of which corresponds to an input range of the A/D converter 154, by the amplifier circuit 153. The voltage signal converted by the amplifier circuit 153 is input into the A/D converter 154 via a bandpass filter (BPF) 166 and then is fed to a predetermined port of the microcomputer including the CPU 152. The A/D converter 154 is an external high-precision A/D converter with a 16-bit resolution.

[0151] Because the analog bandpass filter 166 is put at the preceding stage of the A/D converter 154 to pass the frequency of 1 kHz to 10 kHz, the low-frequency mechanical vibration and the aliasing caused due to an upper limit frequency in the A/D conversion can be prevented. This filtering function can be replaced with a digital filter such as PLD, or the like that is put at the subsequent stage of the A/D converter. Such preprocess filtering may be executed in the CPU calculation, but the preprocess filtering is separated from the CPU calculation because a processing speed and a program size are influenced.

[0152] Since the A/D converted value is obtained as the signed integer, a full-wave rectified waveform can be derived by calculating an absolute value of a finite-time wave. Because the full-wave rectified waveform is finite, the FFT operation is executed after an influence of both ends is lessened by applying the Window process. Since a floating-point operational unit is not provided to the microcomputer containing the CPU 152, a fixed point operation that can be calculated by using the integer only is used.

[0153] The resultant frequency distribution is compared with the frequency of an envelope having a damping waveform decided by the rotating speed and the number of the rolling elements in order of higher intensity. At this time, bearing specifications stored in the external memories 157, 158 and the speed value derived from the rotating pulse generator 164 are employed.

[0154] The piezoelectric sensor 162 can get acoustic/elastic wave/AE signals. But its sampling frequency is set to 100 kHz for the purpose of sensing the flaking/damage mainly.

[0155] The voltage signal generated by the temperature sensor 163 is input into the A/D converter 155 via the amplifier circuit (not shown) and is given to a predetermined port of the microcomputer including the CPU 152. The A/D converter 155 is an external high-precision A/D converter with 10-bit resolution. The temperature sensor 163 and the rotating pulse generator 164 are set to a sampling frequency that is lower than that of the piezoelectric sensor 162.

[0156] The external memory 156 is formed of RAM, and the external memories 157, 158 are formed of ROM. Also, the communication circuit 159 is composed of a LAN interface, and is connected to a LAN line (Local Area Network) 167 via a twisted pair, a coaxial cable, an optical fiber cable, or the like. When a radio LAN is employed, the communication circuit 159 is connected to the LAN line 167 via radio. The communication circuit 160 gives a serial communication interface, and is connected to a program loading/diagnostic data transmitting and receiving terminal 168.

[0157] The communication circuit 160 is used to transmit/receive in serial an extent of coincidence between the sensed frequency and respective flaw frequencies of the outer ring, the inner ring, the rolling elements, and the retainer of the bearing 21. A parallel-type communication circuit may be employed if it is used within a short distance. Preferably a dedicated IC for ensuring a security should be interposed in the communication line.

[0158] The machinery facility abnormality diagnosis system 151 further includes a timer counter (TMUCNT) 169, a direct memory access controller (DMA) 170, an interruption controller (INTC) 171, a D/A converter (DAC) 172, and an active gain control (AGC) 173. The D/A converter 172 is connected to a diagnostic output connector and/or display 174.

[0159] The timer counter 169 counts up a pulse signal generated by the rotating pulse generator 164 and then gives the number of counted pulses to a predetermined port of the microcomputer including the CPU 152.

[0160] The interruption controller 171 and the timer counter 169 are used to feed the signal to the microcomputer including the CPU 152 at a predetermined sampling period. Normally the data are transferred to the external memory 156 via the microcomputer including the CPU 152. But the direct transfer may be applied by the direct memory access controller 170 to shorten extremely the sampling period.

[0161] When the operator can come close to the diagnosis unit 161 or when the diagnosis unit 161 can be put near the machine operator, the diagnostic output connector and/or display 174 is used to give the LED display or the liquid crystal screen display via the LCD driver, give the sound output using the D/A output, or the like.

[0162] In the machinery facility abnormality diagnosis system 151, all the data digitized by the signal processing are calculated by the microcomputer including the CPU 152, and various processing programs are loaded on the external memories 157, 158 attached separately. Also, since at least one machinery facility abnormality diagnosis system 151 is used in one unit of the bearing 21, the specifications (dimensions of respective portions, material, number of the rolling elements, lubricant, date of manufacture) of the bearing 21 and the specifications (frequency characteristic, sensitivity) of the sensors 162, 163, 164 are stored in the external memories 157, 158.

[0163] Also, since RMS, peak, crutosis, peak factor, etc. are assigned to predetermined addresses of the external memory 156 as amplitude parameters, the external device can inquire about the data by using the communication function.

[0164] In the machinery facility abnormality diagnosis system 151, the piezoelectric sensor 162, the temperature sensor 163, and the rotating pulse generator 164 for sensing acoustic/ elastic wave, ultrasonic wave, and mechanical vibration, for example, are fitted to the bearing 21, and then the diagnosis unit 161 capable of amplifying/digitizing the signals generated by these sensors, then applying the calculating process to the signals by virtue of the microcomputer containing the CPU 152, and then outputting the calculated result is installed into the single case 161A. For this reason, the condition of the bearing 21 can be monitored with a simple configuration without overhaul and also the defect or the abnormality of the bearing 21 can be inspected. As a result, time and labor required to overhaul and assemble the bearing 21 can be reduced and the damage of the bearing 21 caused by the overhauling and the assembling can be prevented. In addition, since the monitoring can be executed effectively with good precision, the higher-precision diagnosis can be carried out and thus the defect that the visual inspection could overlook can be found. Also, the diagnosis unit 161 can be installed into various machinery equipments other than the bearing 21 because such diagnosis unit 161 can be formed in a compact size by using small-size sensors, the microcomputer, IC, and the circuit board, and the diagnosis unit 161 can be installed flexibly into various machinery equipments because such diagnosis unit 161 can have a communication capability, so that the diagnosis unit 161 can contribute to the reduction in a cost aspect and the energy saving measure. Since the ultrasonic pulse echo approach can be utilized by providing not only a function of amplifying the signals from respective sensors but also a function of sending the pulse signal to the piezoelectric sensor 162, for example, to the diagnosis unit 161, the damage of the mechanical sliding surface in the stationary time and the metal contact condition between the sliding surfaces in the running time can be sensed/diagnosed.

[0165] Also, in the machinery facility abnormality diagnosis system 151, one or more out of temperature, vibration displacement, vibration speed, vibration acceleration, force, distortion, acoustic, acoustic emission, ultrasonic wave, and rotating speed can be sensed by the piezoelectric sensor 162, the temperature sensor 163, and the rotating pulse generator 164. Therefore, the condition of the bearing 21 can be monitored without fail and also the defect or abnormality of the bearing 21 can be inspected without fail.

[0166] Also, in the machinery facility abnormality diagnosis system 151, the microcomputer containing the CPU 152, the amplifier circuit 153, the A/D converter circuits 154, 155, the external memories 156, 157, 158, the communication circuits 159, 160, the timer counter 169, the direct memory access controller 170, the interruption controller 171, the D/A converter 172, and the active gain control 173 are employed in the calculating process. Therefore, the diagnosis system that is excellent in a cost aspect can be realized by using a combination of the general-purpose parts without custom parts.

[0167] Also, in the machinery facility abnormality diagnosis system 151, one process or more out of calculation of feature parameters of a standard deviation and a peak factor, envelope detection, FFT, filter, wavelet transform, short-time FFT, and calculation of a feature frequency due to the defect of the rotating body and the comparing/deciding processes can be executed in a digital fashion. Therefore, since the monitoring can be executed effectively with good precision, the higher- precision diagnosis can be carried out and thus the defect that the visual inspection could overlook can be found surely.

<Ninth embodiment>

[0168] FIG.35(a) and FIG.35(b) show a machinery facility abnormality diagnosis system according to a ninth embodiment of the present invention.

[0169] In a machinery facility abnormality diagnosis system 181 of the ninth embodiment, an impact sensor 183 that is formed as a bimorph of a piezoelectric ceramic element is installed a case 182A of a diagnosing unit 182, and also the impact sensor 183 and the temperature sensor 163 are arranged integrally in the case 182A. Since other configurations are similar to those in the eighth embodiment, the same reference numbers as those in the eighth embodiment are affixed to the common configurations, and thus explanation about them will be omitted herein.

[0170] In the machinery facility abnormality diagnosis system 181, an impact generated when the bearing 21 goes down is detected. Normally, the feature parameter computing expressions for the natural impulse elastic waves generated at the time of failure of the bearing 21 are stored in the external memory 158. If the feature parameter decided based on a waveform signal, which is digitized via the impact sensor 183, an amplifier filter portion 184, and the A/D converter 155 as the high-precision external A/D converter with 10-bit resolution, and the rotation speed has the dimension, mean value of the vibration value, standard deviation (rms), maximum value, peak (average of ten values counted from the maximum absolute value), etc. are calculated previously. Meanwhile, if the feature parameter is dimensionless, wave waveform, peak factor, impact index, skewness, crutosis, etc. are calculated previously. The approach of sensing the defect of the bearing 21 from the frequency domain data, which is obtained by the FFT operation by the microcomputer including the CPU 152, is similar to the seventh embodiment. In this event, the impact sensor 183 and the amplifier filter portion 184 may be integrated as far as the frequency band permits.

[0171] The data of cross frequency of the feature parameter in other frequency domain, extreme frequency, degree of irregularity, degree of contain of the rotating frequency, degree of contain of the rotating frequency harmonics, degree of contain of the defect feature frequency component powers of respective parts of the bearing 21, etc. are registered in the external memory 156, and then are updated in a predetermined period.

[0172] The degradation diagnosis of the bearing 21 by the feature parameters may be executed by the microcomputer including the CPU 152 in the case 182A. Alternately, if the diagnosis is recognized by using the regression analysis in which a large number of parameters are related complicatedly or the learning algorithm using the neural network, the data may be processed by transmitting the data to the computer, into which the recognition program is installed, separately via the LAN line 167, or the like. Otherwise, it is preferable that the custom IC exclusively used for the recognition program or another microcomputer should be added.

[0173] In the machinery facility abnormality diagnosis system 181, the diagnosis unit 182 can be constructed by using small- size electronic parts, small-size sensors, and short wirings in addition to the microcomputer including the CPU 152. Thus, such diagnosis unit 182 can be installed into the space-saving case 182A and thus the inspection/diagnosis can be executed by such diagnosis unit 182 incorporated into the bearing 21. Also, the diagnosis unit 182 can be constructed in a compact size, and a cost can be further reduced by omitting the signal line extended from the sensors to the calculating/processing device.

<Tenth Embodiment>

[0174] FIG.36 shows a machinery facility abnormality diagnosis system according to a tenth embodiment of the present invention.

[0175] In a machinery facility monitoring system 191 of the tenth embodiment, a DSP (digital signal processor, capable of executing a product-sum operation in a filtering operation and a data transfer at a high speed) 192 is incorporated into the calculating/processing portion.

[0176] In this embodiment, the eighth and ninth embodiments are revised such that the DSP 192 takes charge of the digital signal processing such as digital filtering, FFT, and the like and also the microcomputer containing the CPU 152 executes other processes. Also, for the same purpose, the calculating/processing portion can be constructed by using a PLD (programmable logic device) without the DSP.

[0177] In the above embodiment, the sliding member that is diagnosed to check whether or not the abnormality is present is not limited to the rolling bearing. More particularly, the sliding bearing, and the like correspond to the sliding member in addition to various rolling bearings. Also, constituent parts of the longitudinal motion mechanism such as the ball screw, the linear guide, etc. correspond to the sliding member as the diagnosis object of the present invention. Also, various large-size rotary sliding members such as the gear or the wheel of the railway vehicle, etc., which take enormous time and labor to remove and fit, can be selected as the abnormality diagnosis object of the present invention.

[0178] In the above embodiment, the machinery facility abnormality diagnosis system itself is equipped with the controlling/processing portion that feeds back the signal responding to the decision result to a controller that controls an operation of the mechanism, into which the sliding members are incorporated, of the machinery facility such that the sensing of the abnormality by this abnormality diagnosis system leads quickly to the maintenance and the operation management of the machinery facility. However, the controlling/ processing portion may be constructed as the independent equipment (system) that can be connected to the abnormality diagnosis system.

<Eleventh Embodiment>

[0179] Next, a machinery facility condition monitoring system according to an eleventh embodiment of the present invention will be explained hereunder. In this event, the same reference symbols are affixed to the portions similar to those in the fifth embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0180] As shown in FIG.37, a railway vehicle facility 210 as a machinery facility, to which a condition monitoring system 230 (see FIG.38) is applied, includes a double row tapered roller bearing 211 as at least one of the rotating body and the sliding member as the sensed object and a bearing housing 212 constituting a part of the railway vehicle carriage.

[0181] The double row tapered roller bearing 211 has a pair of inner rings 214, 214 having inner ring raceway surfaces 215, 215 inclined like a tapered outer surface on their outer peripheral surfaces, a single outer ring 216 having a pair of outer ring raceway surfaces 217, 217 inclined like a tapered inner surface on an inner peripheral surface, tapered rollers 218 as a plurality of rolling elements arranged in double rows between the inner ring raceway surfaces 215, 215 of the inner rings 214, 214 and the outer ring raceway surfaces 217, 217 of the outer ring 216, annular pressed retainers 219, 219 for holding reliably the tapered rollers 218, and a pair of sealing members 220, 220.

[0182] The bearing housing 212 has a housing 221, a front lid 222 fitted to a front end portion of the housing 221, and a rear lid 223 fitted to a rear end portion of the housing 221.

[0183] An axle 224 is press-fitted into the inner ring of the double row tapered roller bearing 211. A radial load imposed by weights of various members, etc. and any axial load are applied to the double row tapered roller bearing 211. An upper area of the outer ring 216 serves as a loading range. Where the loading range denotes an area in which the load is applied to the rolling element.

[0184] The housing 221 constitutes a side frame of the railway vehicle carriage, and is formed like a circular ring to cover the outer peripheral surface of the outer ring 216. A pair of recess portions 225, 225 are formed on the outer peripheral surface of the housing 221 in the center portion of each row of the double row tapered roller bearing 211 in the axial direction. The recess portions 225, 225 receive therein the sensor units 22, 22 constituting a part of the condition monitoring system 230 and having the same configuration as the first embodiment.

[0185] Next, the condition monitoring system 230 of the eleventh embodiment will be explained hereunder. The condition monitoring system 230 is different from the fifth embodiment only in the process that is executed by a comparing/deciding portion 252 in a calculating/processing portion 250 constructed by the microcomputer, but the processes in the sensing/ processing portion 20 and the controlling/processing portion 40 are equivalent to the abnormality diagnosis system in the fifth embodiment. In other words, the condition monitoring system 230 includes the sensing/ processing portions 20, 20 having the sensor units 22, 22 provided to the rows of the double row tapered roller bearing 211 respectively to output the condition of respective rows as the electric signal, the calculating/processing portions 250, 250 for calculating/processing the electric signals output from the sensor units 22, 22 to decide the conditions such as the defect, the abnormality, or the like of the railway vehicle facility 210, and the controlling/processing portion 40 for controlling/ outputting the decision result of the calculating/processing portions 250, 250.

[0186] The sensor units 22, 22 has sensors as a plurality of sensing elements that can sense the information such as sound J1, temperature J2, vibration J3, rotation speed J4, distortion J5, AE (acoustic emission), moving speed, force, ultrasonic wave, etc., which are generated from the machinery facility during the running, as the physical quantity that changes in response to the rotating state of the bearing 211 and then output the information to the calculating/ processing portions 250, 250 as the electric signal. Here, since the calculating/ processing portions 250, 250 can appropriately distribute/ process the electric signals every sensed information, a plurality of sensing elements for sensing independently the particular signal such as sound, temperature, vibration, rotation speed, distortion, AE, moving speed, force, ultrasonic wave, or the like respectively may be employed in combination as the sensor units 22, 22, otherwise a composite sensor unit capable of sensing a plurality of information at the same time may be employed as the sensor unit 22.

[0187] Also, the fitting position of the sensor unit 22 is selected on the outer peripheral portion of the housing 221 in the loading range of the radial load. Therefore, when the damage is caused on the bearing raceway surface, for example, a collision force generated when the rolling element passes over the damaged portion is larger in the loading range than the non-loading range. Thus, the abnormal vibration can be sensed in the loading range of the bearing with good sensitivity.

[0188] In addition, the sensor unit 22 is fitted into the recess portion 225 formed in the housing 221. Therefore, since the sensor unit 22 is never affected by the fitting state of the sensor unit 22 and the surrounding environment (noise, moisture, wind pressure, etc.), the signal can be sensed at a high SN ratio (noise-to-signal ratio) with high precision. Here, the sensor unit 22 may be incorporated into the rotating body, the sliding member, or the like.

[0189] Also, it is preferable that the function or the process of waterproof, oil-resistant, dustproof, rust-preventive, moisture-proof, heat-resistant, and electromagnetic noise- resistant properties should be added or applied to the sensor unit 22 to lessen the influence of the noise. In addition, it is more preferable that an amplifier function should be built

in the sensing/processing portions 20, 20 and thus there is no need to provide the special amplifier and the anxiety in regard to the entering of the noise from the intermediate cable, or the like can be removed.

[0190] The calculating/processing portions 250, 250 execute the calculating/processing operations to decide the condition such as the defect, the abnormality, or the like of the machinery facility based on the electric signals output from the sensing/ processing portions 20, 20. Such operations are executed by the microcomputer. The microcomputer consists of an IC chip on which CPU, MPU, DSP, etc. are mounted, a memory, and the like.

[0191] As shown in FIG.39, each of the calculating/processing portions 250, 250 includes the data accumulating/distributing portion 31, the temperature analyzing portion 32, the rotation analyzing portion 33, the filtering processing portion 34, the vibration analyzing portion 35, the comparing/deciding portion 252, and the internal data saving portion 37. These portions except the comparing/deciding portion 252 have the equivalent functions to those in the first embodiment.

[0192] The data accumulating/distributing portion 31 receives the electric signals fed from respective sensing elements and accumulates them temporarily, and also has collecting and distributing functions of allocating the signal to any of the analyzing portions 32, 33, 35 in response to the type of the signal. Various signals are A/D-converted into the digital signal by an A/D converter (not shown) before they are fed to the data accumulating/distributing portion 31, then are amplified by an amplifier (not shown), and then are sent to the data accumulating/distributing portion 31. In this event, the A/D conversion and the amplification may be applied in reverse order.

[0193] The temperature analyzing portion 32 calculates the temperature of the bearing 211 based on the output signal from the sensing element that senses the temperature information J2, and then transmits the calculated temperature to the comparing/deciding portion 252. The analyzing portion 32 has a temperature conversion table that responds to characteristics of the sensing elements, and calculates the temperature data based on a level of the sensed signal.

[0194] The rotation analyzing portion 33 calculates the rotation speed of the inner ring 214, i.e., the axle 224, based on the output signal from the sensing element that senses the rotation speed information J4, and then transmits the calculated rotation speed to the comparing/deciding portion 252. In this case, when the sensing element is composed of an encoder fitted to the inner ring 214, a magnet fitted to the outer ring 216, and a magnetism sensing element, the signal output from the sensing element is given as a pulse signal that responds to a shape of the encoder and the rotation speed. The rotation analyzing portion 33 has a predetermined transformation function or transformation table in response to a shape of the encoder, and then calculates the rotation speed of the inner ring 214 and the axle 224 in compliance with the function or the table.

[0195] The vibration analyzing portion 35 executes the frequency analysis of the vibration generated in the bearing 211, based on the output signal from the sensing element that senses the vibration information J3. More particularly, the vibration analyzing portion 35 is an FFT calculating portion for calculating the frequency spectrum of the vibration signal, and calculates the frequency spectrum of the vibration based on the FFT algorithm. Then, the calculated frequency spectrum is transmitted to the comparing/deciding portion 252. Also, the vibration analyzing portion 35 may execute the absolute-value process and the envelope process as the preprocessing of FFT, and may convert the frequency spectrum into the frequency component necessary for the diagnosis only. The vibration analyzing portion 35 may also output the envelope data obtained after the envelope process to the comparing/deciding portion 252, as the case may be.

[0196] Normally, the abnormal frequency band of the vibration generated due to the rotation of the bearing are decided depending upon a size of the bearing, the number of the rolling elements, etc. The relationships between the defects of respective members of the bearing and the abnormal vibration frequencies generated in respective members are given as shown in FIG.4. In the frequency analysis, the maximum frequency at which the Fourier transform can be applied (Nyquist frequency) is decided according to the sampling time. Thus, preferably the frequency that is in excess of the Nyquist frequency should not be contained in the vibration signal. Therefore, the present embodiment is constructed such that the filtering processing portion 34 is provided between the data accumulating/distributing portion 31 and the vibration analyzing portion 35, then a predetermined frequency band is cut out by the filtering processing portion 34, and then the vibration signal containing only the cut-out frequency band is transmitted to the vibration analyzing portion 35. When the axle is rotating at a low speed in the railway vehicle, only the frequency component of 1 kHz or less, for example, may be extracted.

[0197] In FIG.39, the temperature analyzing portion 32, the rotation analyzing portion 33, and the vibration analyzing portion 35 are illustrated. The analyzing portions may be provided in answer to the information that are sensed by respective sensing elements in the sensor unit.

[0198] The comparing/deciding portion 252 compares/collates the results analyzed by the temperature analyzing portion 32, the rotation analyzing portion 33, and the vibration analyzing portion 35 with the information as the diagnosis reference, which is used to check the presence or absence of the abnormality of the bearing, every first time period t_1 to provisionally diagnose whether or not the abnormality is generated in the bearing. Also, the comparing/deciding portion 252 transmits the provisional diagnosis results, which have been compared/collated every first time period t_1,

to the internal data saving portion 37 to save them.

[0199] In addition, when the comparing/deciding portion 252 has executed the comparison/decision predetermined number of times or a second time period t_2 that is longer than the first time period t_1 has elapsed, such comparing/deciding portion 252 makes the total evaluation, in which the bearing is considered as the abnormal state when the number of times the bearing is diagnosed provisionally as the abnormality exceeds a threshold value, based on the provisional diagnosis results saved in the internal data saving portion 37, and thus diagnoses the presence or absence of the abnormality in the bearing and its abnormal location. In this event, the total evaluation may be constructed to decide an extent of abnormality based on the number of times the bearing is diagnosed provisionally as the abnormal state and then diagnose the presence or absence of the abnormality and its abnormal location.

[0200] More specifically, the comparing/deciding portion 252 compares/collates the frequency spectrum of the vibration calculated by the vibration analyzing portion 35 with the reference values saved in the internal data saving portion 37 every first time period t_1 to provisionally diagnose whether or not the abnormal vibration is being generated. Where the reference values are data values of frequency components due to the wear and the damage of the particular location of the bearing calculated based on the rotation speed signal of the period signal as the operating signal of the machinery facility.

[0201] As the provisional diagnosis processing method executed by the comparing/deciding portion 252 based on the vibration information, any one of above methods (1) to (3) and (5) to (6) may be employed.

[0202] The comparing/deciding portion 56 executes the comparison/collation every first time period t_1 by using the above methods (1) to (3) and (5) to (6), and then transmits the provisional diagnosis result about the presence or absence of the abnormality to the internal data saving portion 37 to save the result therein. Also, when the comparing/deciding portion 252 has executed the comparison/decision predetermined number of times or a second time period t_2 that is longer than the first time period t_1 has elapsed, such comparing/deciding portion 252 makes the total evaluation, in which the bearing is considered as the abnormal state when the number of times the bearing is diagnosed provisionally as the abnormality exceeds a threshold value, based on the provisional diagnosis results saved in the internal data saving portion 37, and thus diagnoses the presence or absence of the abnormality in the bearing and its abnormal location.

[0203] In this case, the result of each sensed object in the comparing/deciding portion 56 may be saved in a storing medium such as memory, HDD, or the like, or the result may be transmitted to the controlling/processing portion 60.

[0204] The controlling/processing portion 40 has the result outputting portion 42 as a displaying means for displaying the analyzed result and the decision result of the calculating/ processing portions 250, 250 in a predetermined display mode, and the controller 41 for feeding back the control signal responding to the decision result of the comparing/deciding portion 252 to the control system that controls the operation of the driving mechanism of the vehicle into which the bearing 211 is fitted.

[0205] More particularly, the result outputting portion 42 informs of the analyzed result and the decision result of the calculating/processing portion 250 by the monitor, the image display, the printing output to the printer, and also informs of the abnormality by the alarm device such as the light, the buzzer, or the like when the decision result of the comparing/deciding portion 252 indicates that the abnormality exists.

[0206] For example, when the decision result of the comparing/ deciding portion 252 indicates that the abnormality is present, the controller 41 feeds the control signal indicating the travel stop of the vehicle, the reduction of speed, or the like to a travel controller of the vehicle in response to an extent of the abnormality. In the present embodiment, a plurality of sensor units 22 measures continuously the condition of the bearing of the bearing unit, and the calculating/processing portion 250 conducts sequentially the abnormality diagnosis based on the measured data. Therefore, the controlling/processing portion 40 informs of the abnormality immediately to execute the control of the vehicle when the abnormality occurs. In other words, a flow of sensing, analyzing, deciding, and result outputting are carried out in real time.

[0207] In this case, any means may be employed to transmit the signal between the sensing/processing portion 20, the calculating/processing portion 250, and the calculating/ processing portion 250 if the signal can be transmitted/received precisely. The cable may be employed or the radio may be employed in light of the network.

[0208] Next, the diagnosis process in the condition monitoring method in the present embodiment will be explained with reference to FIG.40 hereunder.

[0209] First, a counter in the microcomputer is initialized into n=0 (step S601), and the diagnosis is started. Then, the signal such as the sound, the vibration, or the like generated from the railway vehicle facility 210 and sensed by the sensor in the sensing/processing portion 20 is input into the microcomputer (step S602). Then, the signal generated from the railway vehicle facility 210 is converted into the digital signal by the A/D converter (step S603). Then, the digital signal is subjected to the amplifying process by the amplifier (step S604). After the amplifying process is executed, the counted value of the counter is set to n=n+1 (step S605). Then, the filtering process is applied to the amplified digital signal by the filtering processing portion 34 (step S606), and thus the noise component is removed or the particular frequency component is extracted.

[0210] Then, the digital signal, after the filtering processing, is sent to the vibration analyzing portion 35, and the analyzing process such as the enveloping process, the frequency analysis, etc. are executed there (steps S607, S608). Thus, the frequency components based on the actually measured data representing the signals sensed from the railway vehicle facility 210 are derived. Meanwhile, the rotation speed signal of the railway vehicle facility 210 is sensed by the sensor in the sensing/processing portion 20 (step S609). Then, a theoretical frequency component generated due to the damage of the railway vehicle facility 210 and serving as a reference value is calculated based on the rotation speed signal (step S610). Then, the frequency components based on the actually measured data are compared/collated with the theoretical frequency component calculated in step S610 by the comparing/deciding portion 252 every first time period t_1 according to any of the above approaches (1) to (3) and (5) to (6) (step S611), and the provisional diagnosis to check whether or not the abnormality is present in the particular location of the railway vehicle facility is executed. The result is saved together with the counter value n in the internal data saving portion 37 (step S612).

[0211] Then, the counter value n is compared with a predetermined number of times N (step S613). Then, if the counter value n is smaller than the predetermined number of times N, the process goes back to step S602 and then the processes in steps S602 to S612 are repeated. In contrast, if the counter value n is in excess of the predetermined number of times N, the evaluation in which the bearing is considered as the abnormal state when the number of times the bearing is diagnosed as the abnormal state in the provisional diagnosis exceeds the threshold value (referred to as the "total evaluation" hereinafter) is executed by using N saved results, and thus the presence or absence of the abnormality in the railway vehicle facility 210 and its location are diagnosed (step S614). Then, the diagnosis result is saved or is fed to the controlling/processing portion 40, and then the diagnosis result is displayed (step S615) or the feedback control is applied by the controlling portion 41. Thus, the diagnosis is ended.

[0212] As a consequence, in the condition monitoring method in the present embodiment, the total evaluation in which the presence or absence of the abnormality and its location are diagnosed by using plural compared/collated results is employed. Therefore, the influence of the impulsive noise, etc. upon the diagnosis can be lessened and thus the monitoring can be executed effectively with good precision.

[0213] In the present embodiment, since the frequency component is compared/collated every first time period t_1, the timing in the total evaluation may be evaluated by employing any second time period t_2 longer than the first time period t_1 instead of the predetermined number of times N.

[0214] Also, the amplifying process and the filtering process in the condition monitoring method in the present embodiment may be executed arbitrarily, and thus carried out as the case may be.

[0215] In addition, in step S114 in FIG.40, the total evaluation in which the presence or absence of the abnormality and its location are decided by comparing the number of times the bearing is provisionally diagnosed as the abnormal state with the threshold value is employed. Alternately, as a variation of the present embodiment, the condition monitoring can be executed by using the total evaluation in which an extent of the damage is decided based on the number of times the bearing is provisionally diagnosed as the abnormal state. As a result, the maintenance can be applied on schedule to the machinery facility an operation of which is not immediately stopped, or the like.

[0216] In the present embodiment, the condition monitoring is applied to the double row tapered roller bearing in the railway vehicle facility. But the condition monitoring may also be applied to other machinery facilities such as a machine tool, the windmill, and others.

[0217] Also, the double row tapered roller bearing as the rolling bearing is employed as the rotating body or the sliding member. But the condition monitoring method and system can also be applied to the ball screw, the linear guide, the linear ball bearing, or the like in addition to the rolling bearing. In this case, as the operation signal of the machinery facility used to calculate the reference value in the comparison/ collation, the rotation speed signal is used in the case of the rolling bearing, the ball screw, or the like as the rotating body whereas the moving speed is used in the case of the linear guide, the linear ball bearing, or the like as the sliding member.

[0218] Further, if the sensor including at least one sensing-element selected from at least sound, temperature, vibration, rotation speed, distortion, AE, and moving speed is provided, the presence or absence of the abnormality can be analyzed by the condition monitoring method and system. But it is preferable that the presence or absence of the abnormality should be analyzed by using at least one of the sensing elements of sound, vibration, and AE. Also, from an aspect of capable of utilizing the past abnormality database, it is desired to analyze the presence or absence of the abnormality by using the vibration information. However, in case the abnormality should be sensed in an initial stage of occurrence of the minute crack or in case the internal defect should be sensed, it is appropriate to employ the AE information in place of the vibration information. If the temperature information is employed in combination with the vibration information or the AE information, such information can have the larger effect than the case where such information is employed solely.

<Twelfth Embodiment>

[0219] Next, a machinery facility abnormality diagnosis system according to a twelfth embodiment of the present

invention will be explained hereunder. In this event, the same reference symbols are affixed to the portions similar to those in the first embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0220] FIG.41 is a view showing a bearing housing 301 of the railway vehicle bearing unit serving as the machinery facility to which an abnormality diagnosis system 310 according to the twelfth embodiment of the present invention is applied. The bearing housing 301 is fitted to cover an end portion of the axle of the railway vehicle, and holds rotatably the axle of the railway vehicle via a bearing (not shown in FIG.41) incorporated into the inside. Also, a cover 302 for covering the end portion of the axle of the railway vehicle is fitted to a housing 303 in the bearing housing 301.

[0221] The bearing housing 301 is fixed by four bolts 304 provided to four corners via the housing 303. Also, a hole used to measure the temperature of the bearing is provided to a side surface of the housing 303 and is stopped with a bolt 305. In the present embodiment, the sensor unit 22 of the above sensing/processing portion 20 is fitted to an end surface of the bolt 304 or the bolt 305, and the signals generated from the bearing in the bearing housing are sensed by respective sensors in the sensor unit 22.

[0222] FIG.42 is a view showing an overall configuration of the abnormality diagnosis system 310 using the sensor unit 22 in the present embodiment. As shown in FIG.42, a rolling bearing 306 is put into the bearing housing 301. The rolling bearing 306 is constructed by arranging rolling elements 309 made of a plurality of balls or rollers between an outer ring 307 fitted into the housing 303 and an inner ring 308 fitted onto the axle of the railway vehicle. Thus, the bearing housing 301 bears rotatably the axle of the railway vehicle via the rolling bearing 306.

[0223] As shown in FIG.42, the sensor unit 22 is fitted to the end surface of the bolt 304 or 305 secured to the surface of the housing 303. The sensor unit 22 can be fitted to the end surface of the bolt 304 used to fix the bearing housing, but the sensor unit may be fitted to the end surface of the bolt 305 used to stop the temperature sensing hole, as described above. Normally this bolt 305 is given to every rolling bearing 6 fitted to the inside. For example, in the case of the double row bearing, the fitting location can be selected on the row located on the wheel side, the row located on the motor side, the middle location, or the like according to the purpose. But it is preferable that, for convenience of the fitting operation, the bolt 305 should be fitted to the wheel side and the sensor unit 22 should be provided to the end surface of the bolt 305. Also, the sensor unit 22 can be fitted to not the end surface of the bolt 305 but the side surface or the inside of the hole that is stopped with this bolt 305.

[0224] It is preferable that the sensor unit 22 and the bolts 304, 305 should be tightly fitted/fixed without unsteadiness, looseness, or the like. More particularly, in view of the running conditions, the fitting conditions, characteristics of the sensor, and so on, the suitable fitting approach can be selected appropriately among various approaches such as screwing, bonding, magnet, inserting, molding integrally with the bolt, etc.

[0225] Also, in case the fitting location of the sensor unit 22 is chosen in the noisy area, preferably the sensor unit 22 should be fitted to be isolated from the circumference. If the sensor can be isolated from the circumference, the noise can be reduced and also the SN ratio can be improved.

[0226] In addition, in order to execute the sensing at the high SN ratio, it is preferable that the sensor unit 22 should be fitted in the loading range of the rolling bearing 306, as indicated by A1 in FIG.5, like the first embodiment. If the sensor unit 22 is fitted to the portion to which the load is applied (loading range), the signal can be sensed with good sensitivity and thus the higher-precision measurement can be done.

[0227] Also, in case the sensor is fitted inevitably in the non-loading range, e.g., when no space is found in the loading range to fit the sensor, when the high-tension cable that emits the noise is provided in the loading range, or the like, it is preferable that the sensing sensitivity of the signal can be enhanced by executing the filtering process.

[0228] Here, the sensor unit 22 has the similar structure/ functions to those of the sensor unit used in the first embodiment. Also, the calculating/processing portion 30 and the controlling/processing portion 40 shown in FIG.42 have the similar structure/functions to those of the sensor unit used in the first embodiment.

[0229] According to the abnormality diagnosis system 310 of the present embodiment, the sensing/processing portion 20 consisting of the sensor unit 22 that is fixed to the end surface of the bolt 304 or 305, which is screwed into the housing 303 of the bearing housing 301 that supports the rolling bearing 306 as the rotating body in the railway vehicle, and has the sensing element to output the signal generated from the rolling bearing 306 as the electric signal, the calculating/processing portion 30 for conducting the abnormality diagnosis of the bearing unit based on the output of the sensor unit 22, and the controlling/processing portion 40 for feeding back the control signal to the control system of the railway vehicle based on the decision result of the calculating/processing portion 30 are provided.

[0230] More specifically, like the first embodiment, the calculating/processing portion 30 includes the data accumulating/distributing portion 31 for accumulating the electric signal fed from the sensing/processing portion 20 and distributing the signal to the suitable distributing route according to the type of the signal, the analyzing portions 32, 33, 35 for calculating the predetermined physical quantity in regarding to the railway vehicle as the machinery facility based on the electric signal distributed from the data accumulating/ distributing portion 31, the internal data saving portion 37 as the first data saving portion in which machine equipment data concerning to the machine equipment are saved, the comparing/ deciding portion 36 for conducting the abnormality diagnosis of the machine equipment by comparing the physical quantity calculated by the analyzing portion with the machine equipment data saved in the internal data

saving portion, and the data accumulating/outputting portion 38 as the second data saving portion for saving the analyzed result by the analyzing portion and the abnormality diagnosis result by the comparing/deciding portion.

[0231] According to the abnormality diagnosis system 310, since the physical information about the rolling bearing 306 are collected by using the sensor unit 22 and the abnormality of the rolling bearing 306 is diagnosed based on the physical information to execute the control, the defect of the rolling bearing 306 can be sensed without decomposition of the bearing housing 301. Therefore, the time and labor required for the decomposition and the assembling of the bearing housing 301 can be reduced and also the damage of the rolling bearing 306 and the bearing housing 301 attendant upon the assembling after the decomposition can be prevented. Also, in the present embodiment, since the diagnosis is made by the abnormality diagnosis system 310 based on the predetermined references, it is possible to find the defect that the visual inspection may overlook.

[0232] Also, according to the present embodiment, since the sensor unit 22 is fixed onto the bolt 304 or 305, there is no need to provide particularly the flat surface, onto which the sensor unit 22 is fitted, on the bearing housing 301. Therefore, the sensor unit 22 can be fitted without reform of the bearing housing 301. As a result, the abnormality diagnosis can be conducted by installing the sensor unit 22 of the abnormality diagnosis system 310 into the bearing housing 301 without extra time/labor and cost.

[0233] In the present embodiment, explanation is made of the rolling bearing in the bearing housing of the railway vehicle as an example, but the present invention is not limited to this. The present invention can also be applied to other rotating parts (gear, wheel itself) of the railway vehicle, the windmill, the reduction gear, the electric motor, the ball screw, the linear guide, and others.

[0234] Also, the calculating/processing portion 30 may have the functions of the calculating/processing portion achieved by the microcomputer 250 in the eleventh embodiment.

[0235] Also, as shown in FIG.43, the calculating/processing portion 30 of the abnormality diagnosis system 310 in the present embodiment may be constructed by the one-chip or one-board microcomputer 81 shown in the fifth to tenth embodiments, or may be constructed by the IC chip. In addition, the controlling/processing portion 40 may also be constructed by the one-chip or one-board microcomputer or the IC chip. Also the microcomputer in which the calculating/processing portion 30 and the controlling/processing portion 40 are integrally provided may be loaded on the machine equipment such as the vehicle, or the like.

[0236] Also, as shown in FIG.44, the controlling/processing portion 40 may be removed from the vehicle and installed on the ground, and then the radio communication may be established between a transmitter/receiver 370 provided on the vehicle and a transmitter/receiver 380 provided adjacent to the railway. In this case, the functions corresponding to the controlling/ processing portion 40 can be provided to the information processing center provided on the ground, for example. This information center may be constructed to receive the information from the microcomputers 81 provided to a plurality of vehicles respectively and to collectively control a plurality of vehicles intensively, for example. In this case, the ID number, or the like may be added to the data sent out from the vehicles respectively to identify the information of respective vehicles. Similarly the sensor unit 22 and the microcomputer 81 may be connected via radio communication.

[0237] As a result, the signal transmission between the sensing/processing portion 20 and the calculating/processing portion 30 or the calculating/processing portion 30 and the controlling/processing portion 40 can be made without a wire connection.

<Thirteenth Embodiment>

[0238] Next, a bearing unit according to a thirteenth embodiment of the present invention will be explained hereunder. As shown in FIG.45, a bearing unit 410 according to a thirteenth embodiment of the present invention is constructed by a double row tapered roller bearing 411, a bearing housing 412 constituting a part of the carriage for the railway vehicle, and an abnormality sensing means 413.

[0239] The double row tapered roller bearing 411 has a pair of inner rings 414, 414 having inner ring raceway surfaces 415, 415 inclined like a tapered outer surface on their outer peripheral surfaces, a single outer ring 416 having a pair of outer ring raceway surfaces 417, 417 inclined like a tapered outer surface on their inner peripheral surfaces, tapered rollers 418 as the rolling elements that are arranged in plural between the inner ring raceway surfaces 415, 415 of the inner rings 414, 414 and the outer ring raceway surfaces 417, 417 of the outer ring 416 in double row, annular pressed retainers 419, 419 for holding reliably the tapered rollers 418, and a pair of sealing members 420, 420.

[0240] A radial load applied by weights of various members, etc. and any axial load are imposed onto the double row tapered roller bearing 411. An upper portion of the outer ring 416 is the loading range of the bearing.

[0241] The bearing housing 412 consists of an axle end member 421, a housing 422, a cover 423, and a shroud 424.

[0242] An inner ring spacer 425 is arranged between the inner rings 414, 414. Also, inner ring spacers 426, 426 are arranged on both outer sides of the inner rings 414, 414 in the axial direction. An axle 401 is fitted into the inner rings 414, 414 and the inner ring spacers 425, 426, 426. The inner ring raceway surfaces 415, 415 of the inner rings 414,

414 restrict the movement of the tapered rollers 418 in the axial direction.

[0243] The outer ring raceway surfaces 417, 417 of the outer ring 416, the inner ring raceway surfaces 415, 415 of the inner rings 414, 414, and the tapered rollers 418 are positioned such that vertexes located on prolonged lines of respective tapered surfaces are converged on one point on the axis line.

[0244] Out of the sealing members 420, 420, one sealing member 420 arranged on the top end portion side of the axle 401 is fitted between the outer end portion of the outer ring 416 and the axle end member 421.

[0245] The other sealing member 420 arranged on the counter top end portion side of the axle 401 is fitted between the outer end portion of the outer ring 416 and the shroud 424.

[0246] The axle end member 421 is fixed by screwing bolts 401a into the top end portion of the axle 401 to cover the inner ring spacer 426 arranged at the top end portion of the axle 401.

[0247] The housing 422 constitutes a side frame of the railway vehicle carriage, and is formed like the annular ring to cover the outer peripheral surface of the outer ring 416. A pair of projected walls 422a, 422a being projected into the inner peripheral surface are mounted on both side end portions of the outer ring 416. Then, a recess portion 422b in which the abnormality sensing means are housed is formed on the outer peripheral surface of the housing 422 corresponding to the center portion of the double row tapered roller bearing 411 in the axial direction. A flat surface 422c is formed on a bottom portion of the recess portion 422b.

[0248] The cover 423 is put on the top end portion of the housing 422. The shroud 424 is positioned between the end portion of the housing 422 and the axle 401 to cover the other sealing member 420 on the counter top end portion side of the axle 401.

[0249] The abnormality sensing means 413 is a composite sensor in which a temperature sensor 427 and a vibration sensor 428 are integrally provided. The temperature sensor 427 is a non-contact type temperature measuring element such as a thermistor temperature measuring element, a platinum resistance temperature sensor, a thermocouple, or the like. The vibration sensor 428 is a vibration measuring element such as a piezoelectric element, or the like.

[0250] Also, since the temperature sensor 427 and the vibration sensor 428 are aligned in the axial direction of the bearing and resin-molded in the recess portion 422b of the housing 422, such temperature sensor 427 and such vibration sensor 428 are integrally molded in a case 429. Thus, the abnormality sensing means 413 is fitted in the loading range of the housing 422 and the double row tapered roller bearing 411 in the center portion in a bearing width. The molding material used in the resin molding is the material that is rich in the waterproof property, the heat resisting property, and the insulating property.

[0251] The temperature sensor 427 senses the temperature of the double row tapered roller bearing 411 via the housing 422 to generate the temperature data signal (voltage signal). The temperature data signal generated by the temperature sensor 427 is transferred to the external controlling portion via a signal carrying means 430 provided in the case 429, and is used to sense the seizure abnormality of the double row tapered roller bearing 411. Here, as the temperature sensor 427, a temperature fuse that does not conduct by causing either a contact of a bimetal to disconnect or a contact to fuse when the atmospheric temperature exceeds a specified value may be employed. In such case, when the temperature of the device exceeds a specified value, conduction of the temperature fuse is cut off and thus the temperature abnormality is sensed.

[0252] The vibration sensor 428 senses the vibration of the double row tapered roller bearing 411 via the housing 422 to generate the vibration data signal (voltage signal). The vibration data signal generated by the vibration sensor 428 is transferred to the external controlling portion via the signal carrying means 430 provided in the case 429, and is used to sense the flaking of the inner ring raceway surfaces 415, 415 and the outer ring raceway surfaces 417, 417 of the double row tapered roller bearing 411, the fracture of the gear, and the flat wear of the wheel. Here, as the vibration sensor 428, any sensor capable of transforming the vibration such as acceleration, speed, displacement, or the like into the electric signal may be employed. When the vibration sensor is fitted to the device that is often exposed to the disturbance such as the noise, and the like, it is desired that the sensor does not suffer the noise by using the insulation type.

[0253] Since the temperature sensor 427 and the vibration sensor 428 are arranged in the case 429 formed by the molding, the entering of the rainwater can be prevented without fail. Also, since the temperature and the vibration can be sensed during the rotation, the defect of a plurality of parts can be inspected concurrently without overhaul of the system into which the rotating parts are incorporated. Since the vibration-proof property against the vibration applied from the outside can be improved rather than the case where the sensor is fixed to the outside of the housing 422, the reliability of the sensing performance can be improved tremendously. Also, since the sensor is never subjected to the surrounding circumstances such as fitting condition, rainwater, wind pressure, and the like in contrast to the case where respective sensors are fixed with the screws separately, the high-precision signal can be generated at the high SN ratio (signal-to-noise ratio).

[0254] As shown in FIG.46, in the first signal processing method in the abnormality sensing means 413, the temperature data signal generated by the temperature sensor 427 and the vibration data signal generated by the vibration sensor 428 are input into a comparator 431 via the signal carrying means 430. Then, the temperature data signal value

given from the temperature sensor 427 is compared with a predetermined temperature threshold value saved in a threshold setting portion 432 in the comparator 431. Similarly, the vibration data signal value given from the vibration sensor 428 is compared with a predetermined vibration threshold value saved in the threshold setting portion 432. That is, at least one abnormality selected from the temperature sensor 427 and the vibration sensor 428 is sensed by the abnormality sensing means 413. At this time, when the temperature data signal value exceeds the temperature threshold value, a temperature abnormality decision signal is output from an abnormality deciding portion 433 and also a temperature abnormality alarm is output from a decision result outputting portion 434.

[0255] Also, when the vibration data signal value exceeds the vibration threshold value, a vibration abnormality decision signal is output from the abnormality deciding portion 433 and also a vibration abnormality alarm is output from the decision result outputting portion 434. The alarm is transferred via cable or radio and then operated. At this time, as the temperature threshold value and the vibration threshold value saved in the threshold setting portion 432 and the temperature/ vibration abnormality decision signals output from the abnormality deciding portion 433, the root-mean-square value and the peak value in any time period may be employed.

[0256] As shown in FIG.47, in the second signal processing method in the abnormality sensing means 413, the vibration data signal generated by the vibration sensor 428 is amplified, then only a predetermined frequency band is extracted from the vibration data signal by a filtering portion 435 to remove the unnecessary frequency band, and then the resultant signal is input into an envelope processing portion 436. The absolute-value detecting process of detecting the absolute value of the waveform is executed in the envelope processing portion 436, then the frequency analyzing process is executed in a frequency analyzing portion 437, and then the actually measured data are transferred to a comparing/collating portion 438.

[0257] Meanwhile, the calculated value data of the frequency components, which are set as those generated due to the abnormality such as one-sided wear, or the like of the bearing, the gear, and the wheel in a theoretical frequency calculating portion 440 based on rotation speed information 439, are transferred to the comparing/collating portion 438. Then, the actually measured data are compared/collated with the calculated value data in the comparing/collating portion 438 to specify the presence or absence of the vibration abnormality and the abnormal location. Then, the presence or absence of the vibration abnormality and the identified location are output from a result outputting portion 441. The information are transferred to the result outputting portion 441 via cable or radio.

[0258] In the second signal processing method, for example, the calculation of the frequency components and the comparison/ collation can be easily made based on the rotation speed information sensed from the electric motor, or the like and design specifications of the rotating elements parts. Also, various data processes and calculation are applied as the processing of the vibration data signal after the amplification. For example, such processing may be executed by the computer, the dedicated microchip, or the like. In addition, the calculation process may be applied to the sensed data signal after such signal is stored in the saving means such as the memory, or the like.

[0259] Also, because it takes much time and labor to exchange the bearing in some machine, such machine cannot be immediately stopped. In this case, in some cases the exchange of the bearing is applied according to a degree of the damage. As the criterion in such case, the root-mean-square value, the maximum value, and the peak factor of the vibration, for example, may be employed with respect to the previously decided reference values.

[0260] Also, as the abnormality diagnosis processing method on the basis of the vibration information in the comparing/ collating portion 438 shown in FIG.46, the above approaches (1) to (6) may be employed.

[0261] According to the bearing unit 410 in the thirteenth embodiment, since the sensors are molded with the resin in the loading range of the bearing housing 412, particularly in the recess portion 422b formed on the housing 422 of the bearing housing 412 that covers the outer peripheral surface of the outer ring 416, the temperature sensor 427 and the vibration sensor 428 can be integrally formed in a single case 429. Thus, the vibration or temperature information accompanying the rotating condition of the rotating parts can be sensed at the same time by sensing at least one abnormality selected from the temperature sensor 427 and the vibration sensor 428 by means of the abnormality sensing means 413. As a result, the defect of a plurality of parts can be inspected simultaneously still in the actual operating state without overhaul of the system into which the rotating parts are incorporated.

[0262] In other words, the abnormality sensing means may be provided in the loading range of the bearing housing. Also, it is preferable that the abnormality sensing means should be secured onto the flat portion provided to a part of the outer peripheral surface of the bearing housing on the loading range side. Like the present embodiment, when the abnormality sensing means is embedded/fixed in the recess portion formed on the bearing housing, preferably such means should be fitted to mold a clearance between the abnormality sensing means and the recess portion. Also, the abnormality sensing means may be arranged on the outer diameter portion of the bearing housing in the loading range and in the center portion of the bearing width.

[0263] In addition, in the present embodiment, the case of the abnormality sensing means has a signal carrying means for sending out the sensed signal, and a decision result outputting portion for deciding/outputting the presence or absence of the abnormality based on the signal sent out via the signal carrying means.

[0264] Further, the inspection executed based on the vibration information is attained by providing the filtering

processing portion for removing the unnecessary frequency band from the vibration waveform from the vibration sensor, the envelope processing portion for detecting the absolute value of the filtered waveform transferred from the filtering processing portion, the frequency analyzing portion for analyzing the frequency of the waveform transferred from the envelope processing portion, the comparing/collating portion for comparing the frequency generated due to the damage calculated based on the rotation speed with the frequency derived based on the actually measured data, and the result outputting portion for identifying the presence or absence of the abnormality and the abnormal location based on the compared result in the comparing/collating portion.

[0265] Therefore, the abnormal decision can be made still in the normal state of use without overhaul of the bearing unit 410. As a result, a frequency of the overhauling/assembling operations that require a lot of time and labor can be reduced and thus the maintenance/administrative costs can be reduced largely. Also, the variation of the decision due to a degree of expertise or the individual differences of the person in charge of inspection is in no way generated rather than the visual inspection in the prior art, and thus the reliability of the abnormality diagnosis can be improved dramatically.

<Fourteenth Embodiment>

[0266] Next, a bearing unit according to a fourteenth embodiment of the present invention will be explained with reference to FIG.48 hereunder. In this event, the same reference symbols are affixed to the portions similar to those in the thirteenth embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0267] As shown in FIG.48, in a bearing unit 450 in the present embodiment, the abnormality sensing means 413 constructed by molding integrally the temperature sensor 427 and the vibration sensor 428 in the case 429 is fixed to the recess portion 422b formed on the outer peripheral surface of the housing 422 via a spacer 451.

[0268] The spacer 451 is made of a metal that has the temperature characteristic and the natural vibration characteristic equivalent to the housing 422. The spacer 451 is fixed by tightening screws 453, 453, which are inserted into a flange 452 arranged on the outer peripheral portion of the housing 422, into the housing 422.

[0269] In this case, the abnormality sensing means 413 as well as the spacer 451 can be detachably attached to the housing 422. Therefore, when the temperature sensor 427 and the vibration sensor 428 are to be exchanged, the exchanging operation can be executed only by taking out the screws 453, 453 not to consume much time. In the bearing unit 450 in the fourteenth embodiment, the same signal processing as that in the first embodiment is applied.

<Fifteenth Embodiment>

[0270] Next, a bearing unit according to a fifteenth embodiment of the present invention will be explained with reference to FIG. 5 hereunder. In this case, the same reference symbols are affixed to the portions similar to those in the thirteenth embodiment, and thus their redundant explanations will be omitted or simplified hereunder.

[0271] As shown in FIG.49, in a bearing unit 460 of the present embodiment, a pair of recess portions 422d, 422d into which the abnormality sensing means is installed are formed on the outer peripheral surface of the housing 422 in the position that corresponds to the center portion in the width area of the inner ring raceway surfaces 415, 415 of the double row tapered roller bearing 411. First and second abnormality sensing means 461, 462 in which the temperature sensor 427 and the vibration sensor 428 are molded integrally in the case 429 are molded in the recess portions 422d, 422d with the resin.

[0272] The recess portions 422d, 422d are also arranged corresponding to the center portion in the width area of the outer ring raceway surfaces 417, 417.

[0273] In this case, the first and second abnormality sensing means 461, 462 are arranged in close vicinity to the position in which the tapered rollers 418 come into contact with the inner and outer ring raceway surfaces 415, 415, 417, 417 while rolling down. Therefore, the sensing sensitivity can be improved further, and a time required until the abnormal signal is generated when the abnormality occurs can be shortened. In the bearing unit 460 of the fifteenth embodiment, the same signal processing as that in the first embodiment is applied.

[0274] Also, the abnormality sensing means in which the temperature sensor and the vibration sensor are molded integrally may be fitted directly to the outer peripheral surface of the housing in the loading range. In such case, the abnormality sensing means should be fitted to the flat portion that is formed on a part of the outer peripheral surface of the housing. Then, the signal processing should be applied in the similar manner to respective embodiments. Also, like the present embodiment, the abnormality sensing means may be arranged on the outer diameter portion of the bearing housing in the loading range and in the width area of the inner ring raceway surfaces or the outer ring raceway surfaces.

[0275] Also, as the bearing used in the bearing unit, a combination of the cylindrical roller bearing and the single row radial ball bearing, or the cylindrical roller bearing or the tapered roller bearing or the self-aligning roller bearing may be applied.

[0276] Here, the machinery facility condition monitoring method and system and the abnormality diagnosis system according to the present invention are not limited to the foregoing embodiments, and appropriate variations, improvements, etc. can be applied. Also, in the present invention, respective embodiments can be employed in combination in the practicable range. Also, the machinery facility of the present invention includes the railway vehicle, the machine tool, the windmill, the reduction gear, the electric motor, and others, and any facility may be employed if the machinery facility includes at least one of the rotating body and the sliding member. Also, the rotating body or the sliding member of the present invention includes the rolling bearing, the sliding bearing, the ball screw, the linear guide, the linear ball bearing, other rotating parts (gear, wheel itself), and others.

[0277] The present invention is explained in detail with reference to particular embodiments, but it is apparent for the person skilled in the art that various variations and modifications can be applied without departing from a spirit and a scope of the present invention.

[0278] This application is filed based on

Japanese Patent Application (Patent Application No.2002-252877) filed on August 30, 2002,
Japanese Patent Application (Patent Application No.2002-338423) filed on November 21, 2002,
Japanese Patent Application (Patent Application No.2002-370800) filed on December 20, 2002,
Japanese Patent Application (Patent Application No.2003-010131) filed on January 17, 2003,
Japanese Patent Application (Patent Application No.2003-048309) filed on February 25, 2003,
Japanese Patent Application (Patent Application No.2003-182996) filed on July 26, 2003,
Japanese Patent Application (Patent Application No.2003-304700) filed on August 28, 2003,

and the contents thereof are incorporated by the reference hereinto.

<Industrial Applicability>

[0279] There is provided the high-precision machinery facility abnormality monitoring system that is capable of deciding the presence or absence of the abnormality in the state of normal use without decomposition of the facility like the machinery facility such as a railway vehicle facility, a machine tool, a windmill, or the like, which requires much time and labor to decompose, and thus capable of reducing the maintenance/ administrative costs and being hardly affected by the noise, and the like.

FIGS.1, 42:

(1) data accumulating/distributing portion 31
(2) temperature analyzing portion 32
(3) rotation analyzing portion 33
(4) filtering processing portion 34
(5) vibration analyzing portion 35
(6) comparing/deciding portion 36
(7) internal data saving portion 37
(8) data accumulating/outputting portion 38
(9) controlling portion 41
(10) result outputting portion 42
(11) amplifier 50
(12) (temperature information)
(13) (rotation information)
(14) (vibration information)
(15) signals
(16) sound information J1
(17) temperature information J2
(18) vibration information J3
(19) rotation speed information J4
(20) distortion information J5

FIG.2(a):

(1) temperature sensing element 22b
(2) rotation sensing element 22c

(3) vibration sensing element 22d
(4) To a calculating/processing portion 30

FIG.2(b):

(1) temperature sensing element 22b
(2) rotation sensing element 22c
(3) vibration sensing element 22d
(4) amplifier 22e
(5) amplifier 22f
(6) amplifier 22g
(7) To a calculating/processing portion 30

FIG.3:

(1) data accumulating portion 31a
(2) sampling reference setting portion 31b
(3) sampling portion 31 c
(4) inputting portion 100
(5) To a temperature analyzing portion 32
(6) To a rotation analyzing portion 33
(7) To a filtering processing portion 34

FIG.4:

(1) flaw of a rolling bearing
(2) frequency after an enveloping process
(3) inner ring (Si)
(4) outer ring (So)
(5) rolling element (Sb)
(6) retainer (Sc)
(7) fr: inner ring rotation speed [Hz]
(8) fc: retainer rotation speed [Hz]
(9) fb: rolling element rotation speed [Hz]
(10) dm: pitch circle diameter [mm]
(11) Z: number of rolling elements
(12) Da: rolling element diameter [mm]
(13) α: contact angle [degree]

FIG.5:

(1) loading range A1
(2) non-loading range A2

FIG.6:

(1) time-variant waveform

FIG.7:

(1) FFT spectrum

FIG.8:

(1) envelope FFT spectrum
(2) frequency component due to damage of the outer ring of the bearing

FIG.9:

(1) sense sound/vibration signals (S101)
(2) A/D conversion (S102)
(3) save in a predetermined format (S103)
(4) frequency analysis (S104)
(5) select a filter bandwidth (S105)
(6) filtering process (S106)
(7) enveloping process (S107)
(8) frequency analysis (S108)
(9) calculate a RMS value (S109)
(10) calculate a frequency due to abnormality of the bearing (S110)
(11) extract an inner ring flaw component Si (Zfi), an outer ring flaw component So (Zfc), a rolling element flaw component Sb (2fb), and a retainer component Sc (fc) (S111)
(12) calculate a reference value (S112)
(13) Si, So, Sb, Sc > reference value (S113)
(14) No abnormality is generated in the bearing (S114)
(15) identify the abnormal position Si(inner ring flaw), So (outer ring flaw), Sb (rolling element flaw), Sc (retainer flaw) (S115)

FIGS.10, 11, 12:

(1) reference value

FIG.13:

(1) sense sound/vibration signals (S101)
(2) A/D conversion (S102)
(3) forming into a digital file (S103)
(4) frequency analysis (S104)
(5) select a filter bandwidth (S105)
(6) filtering process (S106)
(7) enveloping process (S107)
(8) frequency analysis (S108)
(9) calculate a peak value (S201)
(10) calculate a frequency due to abnormality of the bearing (S202)
(11) extract an inner ring flaw component Si (Zfi), an outer ring flaw component So (Zfc), a rolling element flaw component Sb (2fb), and a retainer component Sc (fc) (S203)
(12) Do Si, So, Sb, Sc have a peak value ? (S204)
(13) No abnormality is generated in the bearing (S205)
(14) identify the abnormal position Si(inner ring flaw), So (outer ring flaw), Sb (rolling element flaw), Sc (retainer flaw) (S206)

FIG.14:

(1) $\delta_1(=Y_1-Y_0)>0$ ·①
$\delta_2(=Y_2-Y_1)<0$ ·②
where A (X_0,Y_0), B (X_1,Y_1), C (X_2,Y_2).
When ① , ② are satisfied and
$dy/dx=(Y_1-Y_0)/(X_1-X_0)>1$
or
$dy/dx=(Y_2-Y_1)/(X_2-X_1)<-1$
is satisfied, Y_1 is decided as a peak.

FIG. 15:

(1) Do the primary components coincide with each other ? (S201)
(2) Do the secondary components coincide with each other ? (S202)
(3) Do the secondary components coincide with each other ? (S211)
(4) Do the quaternary components coincide with each other ? (S212)

(5) No abnormality is generated (S321)
(6) The abnormality is generated (S321)

FIG. 16:

(1) collate only the primary, secondary, quaternary components (flaw of the outer ring)
(2) (secondary)
(3) (quaternary)

FIG.17:

(1) reference level L_0 (RMS value f1)
(2) level difference

FIG.18:

(1) a relationship between a size of flaking and a level difference
(2) reference level dB
(3) size of flaking mm

FIG.19:

(1) calculate the abnormal frequency due to the abnormality in the bearing (S401)
(2) extract a primary component due to the inner ring flaw, a primary component due to the outer ring flaw, a primary component due to the rolling element flaw, and a primary component due to the retainer (S402)
(3) extract a natural-number multiple component due to the inner ring flaw, a natural-number multiple component due to the outer ring flaw, a natural-number multiple component due to the rolling element flaw, and a natural-number multiple component due to the retainer (S403)
(4) comparing the primary component with respective natural- number multiple components by referring to reference value (S404)
(5) Is the abnormality generated ? (S405)
(6) The abnormality is generated. Identify the abnormal position (S406)
(7) No abnormality is generated (S407)

FIG.20:

(1) degree
(2) level (dB)
(3) criterion line
(4) roller missing sound
(5) The case where the flaw is generated

FIG.21:

(1) calculate the abnormal frequency due to the abnormality in the bearing (S501)
(2) calculate V_i and V_{RMS} (S502)
(3) calculate a difference between V_i, V_{RMS} or a quotient (S503)
(4) Does the difference or the quotient exceed a reference value ? (S504)
(5) The abnormality is generated. Identify the abnormality occurring location (S505)
(6) No abnormality is generated (S506)

FIGS.22, 23, 24, 25:

(1) frequency Hz
(2) intensity

FIG.26:

(1) temperature sensing element 52b
(2) rotation sensing clement 52c
(3) vibration sensing element 52d
(4) transmitting portion 52h
(5) To the calculating/processing portion 30

FIG.27:

(1) data accumulating portion 31
(2) temperature analyzing portion
(3) rotation analyzing portion
(4) filtering processing portion 34
(5) vibration analyzing portion
(6) comparing/deciding portion 36
(7) internal data saving portion 37
(8) data accumulating/outputting portion 38
(9) controlling portion 41
(10) result outputting portion 42
(11) receiving portion 60
(12) (temperature information)
(13) (rotation information)
(14) (vibration information)
(15) radio communication
(16) signals
(17) sound information J1
(18) temperature information J2
(19) vibration information J3
(20) rotation speed information J4
(21) distortion information J5

FIG.28:

(1) (sensor built-in bearing) 21
(2) <calculating/processing portion> 30
(3) data accumulating/distributing portion 31
(4) temperature analyzing portion 32
(5) rotation analyzing portion 33
(6) filtering processing portion 34
(7) vibration analyzing portion 35
(8) comparing/deciding portion 36
(9) internal data saving portion 37
(10) data accumulating/outputting portion 38
(11) <controlling/processing portion> 40
(12) controller 41
(13) result outputting portion 42
(14) signal transmitting/receiving device 63
(15) information processing center
(16) (temperature information)
(17) (rotation information)
(18) (vibration information)
(19) signals
(20) sound information J1
(21) temperature information J2
(22) vibration information J3
(23) rotation speed information J4
(24) distortion information J5
(25) feedback

FIG.29:

(1) (sensor built-in bearing) 21
(2) data accumulating/distributing portion 31
(3) temperature analyzing portion 32
(4) rotation analyzing portion 33
(5) filtering processing portion 34
(6) vibration analyzing portion 35
(7) comparing/deciding portion 36
(8) internal data saving portion 37
(9) data accumulating/outputting portion 38
(10) result outputting portion 42
(11) calculating/processing portion> 73
(12) controlling/processing portion> 75
(13) (temperature information)
(14) (rotation information)
(15) (vibration information)
(16) signals
(17) sound information J1
(18) temperature information J2
(19) vibration information J3
(20) rotation speed information J4
(21) distortion information J5
(22) remove and bring it to the calculating/processing portion

FIG.30:

(1) <controlling/processing portion> 40
(2) controller 41
(3) result outputting portion 42
(4) <microcomputer> IC chip memory 81
(5) machinery facility 90
(6) <sensing processing portion>
(7) signals
(8) sound information J1
(9) temperature information J2
(10) vibration information J3
(11) rotation speed information J4
(12) distortion information J5

FIG.31:

(1) data accumulating/distributing portion 31
(2) temperature analyzing portion 32
(3) rotation analyzing portion 33
(4) filtering processing portion 34
(5) vibration analyzing portion 35
(6) comparing/deciding portion 36
(7) internal data saving portion 37
(8) <microcomputer> 81
(9) (temperature information)
(10) (rotation information)
(11) (vibration information)

FIGS.32, 33:

(1) <controlling/processing portion> 40
(2) controller 41

(3) result outputting portion 42
(4) <microcomputer> IC chip memory 81
(5) machinery facility 90
(6) signals
(7) sound information J1
(8) temperature information J2
(9) vibration information J3
(10) rotation speed information J4
(11) distortion information J5

FIG.34(a):

(1) piezoelectric sensor signal
(2) temperature data input
(3) rotating pulse input

FIG.35(a):

(1) temperature sensor 163
(2) sensing circuit
(3) impact sensor 183
(4) amplifier filter 184
(5) rotating pulse input

FIG.36:

(1) machinery facility monitoring system 191
(2) peripheral function
(3) sensor signal output
(4) diagnosed feature parameter output diagnosis result output

FIG.38:

(1) <controlling/processing portion> 40
(2) controller 41
(3) result outputting portion 42
(4) <sensing processing portion>
(5) <microcomputer> IC chip memory 250
(6) signals
(7) sound information J 1
(8) temperature information J2
(9) vibration information J3
(10) rotation speed information J4
(11) distortion information J5

FIG.39:

(1) data accumulating/distributing portion 31
(2) temperature analyzing portion 32
(3) rotation analyzing portion 33
(4) filtering processing portion 34
(5) vibration analyzing portion 35
(6) internal data saving portion 37
(7) -calculating/processing portion> 250
(8) comparing/deciding portion 252
(9) (temperature information)
(10) (rotation information)
(11) (vibration information)

FIG.40:

(1) input sound/vibration signals (S602)
(2) A/D conversion (S603)
(3) amplifying process (S604)
(4) filtering process (S606)
(5) enveloping process (S607)
(6) frequency analysis (S608)
(7) rotation speed information (S609)
(8) calculate a theoretical frequency (S610)
(9) compare/collate (S611)
(10) save the result (S612)
(11) decide based on N results whether or not the abnormal is present (S614)
(12) display the result (S615)

FIG.43:

(1) <controlling/processing portion> 40
(2) controller 41
(3) result outputting portion 42
(4) microcomputer 81
(5) signals
(6) sound information J1
(7) temperature information J2
(8) vibration information J3
(9) rotation speed information J4
(10) distortion information J5

FIG.44:

(1) controlling/processing portion 40
(2) microcomputer 81
(3) transmitter/receiver 370

FIG.46:

(1) temperature sensor 427
(2) vibration sensor 428
(3) comparator 431
(4) threshold setting portion 432
(5) abnormality deciding portion 433
(6) decision result outputting portion 434

FIG.47:

(1) vibration sensor 428
(2) filter portion 435
(3) envelope processing portion 436
(4) frequency analyzing portion 437
(5) comparing/collating portion 438
(6) rotation speed 439
(7) theoretical frequency calculating portion 440
(8) result outputting portion 441

FIG.53:

(1) bearing 1131
(2) pickup 1132

(3) AGC amplifier 1133
(4) band-pass filter 1134
(5) RMS calculator 1135
(6) envelope circuit 1136
(7) RMS calculator 1137
(8) alarm circuit 1138
(9) means for deciding whether or not the abnormality is present
(10) amplitude

FIG.54:

(1) abnormality diagnosis system 1140
(2) rolling bearing 1141
(3) microphone 1142
(4) amplifier 1143
(5) electronic device 1144
(6) transducer 1147
(7) abnormality diagnosing portion 1149
(8) filtering processing portion
(9) abnormality deciding portion
(10) analog outputting portion 1150

FIG.55:

(1) A/D conversion 1162
(2) waveform processing portion (enveloping process) 1163
(3) calculating portion 1164
(4) deciding portion 1165
(5) outputting portion 1166
(6) system driving portion

Claims

1. An abnormality diagnosis system for diagnosing a presence or absence of an abnormality of a bearing unit for a railway vehicle axle, comprising:

a sensing/processing portion for outputting a signal generated from the bearing unit as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the bearing unit based on an output of the sensing/processing portion;
a result outputting portion for outputting a decision result of the calculating/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the railway vehicle based on the decision result.

2. An abnormality diagnosis system according to claim 1, wherein the calculating/processing portion includes
a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,
an analyzing portion for calculating a predetermined physical quantity in regarding to the bearing unit based on the electric signal distributed from the data accumulating/ distributing portion,
a first data saving portion for saving bearing unit data in regarding to the bearing unit,
a comparing/deciding portion for making the abnormality diagnosis of the bearing unit by comparing/referring an analyzed result of the analyzing portion with the bearing unit data saved in the first data saving portion, and
a second data saving portion for saving the analyzed result of the analyzing portion and a decision result of the comparing/deciding portion.

3. An abnormality diagnosis system according to claim 2, wherein the analyzing portion includes
a filtering processing portion for removing a noise component of the electric signal fed from the calculating/ processing portion or extracting a particular frequency component to output, and

a frequency analyzing portion for executing a frequency analysis of a signal output from the filtering processing portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on a result of the frequency analysis of the frequency analyzing portion.

4. An abnormality diagnosis system according to claim 2 or 3, wherein the analyzing portion has a temperature analyzing portion that calculates a temperature of the bearing unit based on the signal output from the data accumulating portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the temperature calculated by the temperature analyzing portion.

5. An abnormality diagnosis system according to any one of claims 2 to 4, wherein the analyzing portion has a rotation analyzing portion that calculates a rotation speed of the bearing unit based on the signal output from the data accumulating portion, and

the comparing/deciding portion makes the abnormality diagnosis of the bearing unit based on the rotation speed calculated by the rotation analyzing portion.

6. An abnormality diagnosis system according to any one of claims 1 to 5, wherein the calculating/processing portion outputs data saved in the second data saving portion to the controlling/processing portion in response to the abnormality diagnosis result.

7. An abnormality diagnosis system according to any one of claims 1 to 6, wherein the filtering processing portion extracts only a frequency component of 1 kHz or less.

8. An abnormality diagnosis system according to any one of claims 1 to 7, wherein a sensing element of the sensing/processing portion is arranged on a stationary portion of the bearing unit in a loading range.

9. An abnormality diagnosis system according to any one of claims 1 to 8, wherein the data accumulating/distributing portion does not output the electric signal containing a noise component, which exceeds a predetermined level, to the analyzing portion.

10. An abnormality diagnosis system according to any one of claims 1 to 9, wherein the comparing/deciding portion makes the abnormality diagnosis of the bearing unit by comparing levels of a frequency due to the abnormality and its higher harmonics with a reference value.

11. An abnormality diagnosis system according to any one of claims 1 to 10, wherein the comparing/deciding portion decides that the abnormality is generated when at least one of peak values of the frequency due to the abnormal and its higher harmonics is larger than a predetermined reference value.

12. An abnormality diagnosis system according to any one of claims 1 to 11, wherein the comparing/deciding portion estimates a degree of damage of the bearing unit based on the peak values of the frequency due to the abnormal and its higher harmonics.

13. An abnormality diagnosis system according to any one of claims 1 to 12, wherein the comparing/deciding portion makes the abnormality diagnosis by comparing the levels of the frequency due to the abnormal and its higher harmonics.

14. An abnormality diagnosis system according to any one of claims 1 to 13, wherein the comparing/deciding portion makes the abnormality diagnosis based on a square mean or a partial overall of a frequency band containing the frequency due to the abnormal.

15. An abnormality diagnosis system according to any one of claims 1 to 14, wherein the comparing/deciding portion makes the abnormality diagnosis by applying a cepstrum analysis to a frequency spectrum.

16. An abnormality diagnosis system according to any one of claims 1 to 15, wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via a cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, voltage-proof, and electromagnetic noise-resistant properties respec-

tively.

17. An abnormality diagnosis system according to any one of claims 1 to 15, wherein a radio communicating device is provided to the sensing/processing portion and the calculating/ processing portion and the calculating/processing portion and the controlling/processing portion respectively, and the signal is transmitted therebetween by using the radio communicating device via radio.

18. An abnormality diagnosis system according to any one of claims 1 to 15, wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion and the calculating/processing portion and the controlling/processing portion via the cable that has waterproof, oil-resistant, dustproof, rust-preventive, and moisture-proof functions, and heat-resistant, and electromagnetic noise-resistant properties respectively, or the signal is transmitted therebetween by using the radio communicating device.

19. An abnormality diagnosis system according to any one of claims 1 to 18, wherein the abnormality diagnosis is made in real time.

20. An abnormality diagnosis system according to any one of claims 1 to 18, wherein the abnormality diagnosis is made at a time different from a vehicle traveling time, based on data accumulated in the accumulating portion.

21. An abnormality diagnosis system according to any one of claims 1 to 20, wherein the presence or absence of the abnormality of a bearing in the bearing unit and an abnormality occurring location are diagnosed.

22. An abnormality diagnosis system according to any one of claims 1 to 20, wherein a flat portion of a wheel is diagnosed.

23. An abnormality diagnosis system according to any one of claims 1 to 20, wherein the presence or absence of the abnormality of a gear in the bearing unit and an abnormality occurring location are diagnosed.

24. An abnormality diagnosis system for a machinery facility having a rotating body, comprising:

a sensor unit having a sensor fitted to a constituent parts of the rotating body to sense a physical quantity of the rotating body in a rotating operation;
a calculating/processing portion for deciding a presence or absence of an abnormality of the rotating body by analyzing an output signal of the sensor unit and then comparing an analyzed result with predetermined reference data; and
a controlling/processing portion for displaying the analyzed result of the calculating/processing portion and a decision result of the calculating/processing portion, and controlling an operation of the machinery facility in response to the decision result.

25. An abnormality diagnosis system according to claim 24, wherein the sensor unit has an output amplifying means for amplifying the output signal of the sensor.

26. An abnormality diagnosis system according to claim 24 or 25, wherein the sensor unit has a radio communicating means for transmitting the output signal to the calculating/ processing portion via radio.

27. An abnormality diagnosis system according to claim 26, wherein the calculating/processing portion and the controlling/processing portion are provided to a monitoring base station that is remote from the rotating body.

28. An abnormality diagnosis system according to claim 27, wherein the sensor unit is fitted to a bearing of a railway vehicle, and
the sensor unit diagnoses the abnormality of the bearing.

29. A machinery facility abnormality diagnosis system for sensing a presence or absence of an abnormality of a sliding member or a rotating body in a machinery facility, comprising:

a sensor unit having one of plural sensing elements for sensing a signal emitted from the machinery facility; and
a calculating/processing portion for executing a calculating process to decide the presence or absence of the abnormality in the machinery facility based on an output of the sensing element;

wherein the calculating/processing portion is composed of a microcomputer.

30. A machinery facility abnormality diagnosis system according to claim 29, wherein the sensor unit is incorporated into the sliding member or the rotating body.

31. A machinery facility abnormality diagnosis system according to claim 30, wherein the microcomputer is fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body.

32. A machinery facility abnormality diagnosis system according to claim 29, wherein the microcomputer and the sensor unit are mounted on a single device board, and are fitted to the sliding member or the rotating body or a mechanism parts that supports the sliding member or the rotating body as a single processing unit.

33. A machinery facility abnormality diagnosis system according to any one of claims 29 to 32, wherein the calculating/processing portion is installed in a single casing.

34. A machinery facility abnormality diagnosis system according to claim 33, wherein the sensor unit is arranged integrally in the casing.

35. A machinery facility abnormality diagnosis system according to any one of claims 29 to 34, wherein the sensing element senses at least one of temperature, vibration displacement, vibration speed, vibration acceleration, force, distortion, acoustic, acoustic emission, ultrasonic waves, and rotation speed.

36. A machinery facility abnormality diagnosis system according to any one of claims 29 to 35, wherein the calculating/processing portion includes central processing unit, amplifier, analog/digital converter, filter, comparator, pulse counter, timer, interruption controller, ROM, RRAM, digital/analog converter, communication module, and external interface.

37. A machinery facility abnormality diagnosis system according to any one of claims 29 to 36, wherein the calculating/processing portion executes at least one process or more of calculation of feature parameters of a standard deviation and a peak factor, envelope detection, FFT, filtering, wavelet transform, short-time FFT, calculation of a feature frequency due to a defect of the rotating body and comparison/decision.

38. A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides the abnormality when a number of times the abnormality is provisionally diagnosed exceeds a threshold value, after a comparison/allocation is executed predetermined number of times or based on a compared/allocated result obtained every second time period.

39. A condition monitoring method for a machinery facility having at least one of a rotating body and a sliding member, comprising the steps of:

analyzing a predetermined physical quantity of the machinery facility based on a signal generated from the machinery facility;
provisionally diagnosing a presence or absence of an abnormality of the machinery facility by comparing/allocating an analyzed result with information serving as references to decide whether or not the abnormality is present in the machinery facility, every first time period; and
diagnosing the presence or absence of the abnormality of the machinery facility and an abnormal location, by executing a total evaluation, which decides a degree of the abnormality according to a number of times the abnormality is provisionally diagnosed, after a comparison/allocation is executed predetermined number of times or based on a compared/allocated result obtained every second time period.

40. A machinery facility condition monitoring method according to claim 38 to 39, wherein the signal is A/D-converted into a digital signal, then a process of analyzing a frequency of the digital signal is executed, and then a frequency component generated due to a damage of the machinery facility and calculated based on an operating signal of the machinery facility is compared/allocated with a frequency component derived based on actually measured data every first time period.

41. A machinery facility condition monitoring method according to claim 40, wherein the signal is subjected to an amplifying process and a filtering process.

42. A machinery facility condition monitoring method according to claim 40 or 41, wherein at least one of the rotating body and the sliding member of the machinery facility is any one of rolling bearing, ball screw, linear guide, and linear ball bearing, and the operating signal of the machinery facility is either a rotation speed signal in the rolling bearing and the ball screw or a moving speed signal in the linear guide and linear ball bearing.

43. A machinery facility condition monitoring system for a machinery facility having at least one of a rotating body and a sliding member and using the condition monitoring method set forth in claim 38 or 39, comprising:

at least one sensing/processing portion for sensing a signal generated from the machinery facility;
a calculating/processing portion having a microcomputer that executes a calculating process to decide a condition of the machinery facility based on the signal output from the sensing/processing portion; and
a controlling/processing portion having at least one of a result outputting portion that outputs a decision result of the calculating/processing portion and a controller that feeds back a control signal to a control system of the machinery facility based on the decision result.

44. A machinery facility condition monitoring system according to claim 43, wherein at least one of the sensing/ processing portion and the microcomputer is installed into the rotating body and the sliding member.

45. A machinery facility condition monitoring system according to claim 43 or 44, wherein at least one of the rotating body and the sliding member is a bearing to which a radial load is applied, and
the sensing/processing portion is fixed in a radial load loading range of a bearing housing that is fitted onto a raceway ring of the bearing.

46. An abnormality diagnosis system for a railway vehicle bearing unit using the machinery facility condition monitoring system set forth in any one of claims 43 to 45.

47. An abnormality diagnosis system for a windmill bearing unit using the machinery facility condition monitoring system set forth in any one of claims 43 to 45.

48. An abnormality diagnosis system for a machine tool spindle bearing unit using the machinery facility condition monitoring system set forth in any one of claims 43 to 45.

49. A machine equipment abnormality diagnosis system comprising:

a sensing/processing portion having a sensor unit that is fixed to a bolt screwed into a housing of the machine equipment and outputs a signal generated from the machine equipment as an electric signal;
a calculating/processing portion for making an abnormality diagnosis of the machine equipment based on an output of the sensing/processing portion; and
a controlling/processing portion for feeding back a control signal to a control system of the machine equipment based on a result of the abnormality diagnosis.

50. A machine equipment abnormality diagnosis system according to claim 49, wherein the calculating/processing portion includes
the calculating/processing portion includes
a data accumulating/distributing portion for accumulating the electric signal fed from the sensing/ processing portion and distributing the signal to an appropriate distributing route according to a type of the electric signal,
an analyzing portion for calculating a predetermined physical quantity in regarding to the machine equipment based on the electric signal distributed from the data accumulating/ distributing portion,
a first data saving portion for saving machine equipment data in regarding to the machine equipment,

a comparing/deciding portion for making the abnormality diagnosis of the machine equipment by comparing the physical quantity calculated by the analyzing portion with the machine equipment data saved in the inside data saving portion,

a second data saving portion for saving the analyzed result of the analyzing portion and a result of the abnormality diagnosis of the comparing/deciding portion.

51. A machine equipment abnormality diagnosis system according to claim 49 or 50, wherein the calculating/processing portion and the controlling/processing portion are composed of a microcomputer or an IC chip.

52. A machine equipment abnormality diagnosis system according to any one of claims 49 to 51, wherein the signal is transmitted between the sensing/processing portion and the calculating/processing portion or the calculating/processing portion and the controlling/processing portion without a wire connection.

53. A bearing unit including an inner ring having an inner ring raceway surface, an outer ring having an outer ring raceway surface, a plurality of rolling elements arranged relatively rotatably between the inner ring raceway surface and the outer ring raceway surface, and a retainer for holding reliably the rolling elements, whereby a bearing to which a radial load is applied is arranged in a bearing housing,

the bearing unit comprising:

an abnormality sensing means provided in a loading range of the bearing housing, for sensing an abnormality from at least one selected from a vibration sensor and a temperature sensor installed/fixed in a single case.

54. A bearing unit according to claim 53, wherein a flat portion is provided to a part of an outer peripheral surface of the bearing housing on a loading range side, and the abnormality sensing means is fixed to the flat portion.

55. A bearing unit according to claim 54, wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a center portion of a bearing width.

56. A bearing unit according to claim 53, wherein the abnormality sensing means is arranged on an outer diameter portion of the bearing housing on the loading range side in a width area of the inner ring raceway surface or the outer ring raceway surface.

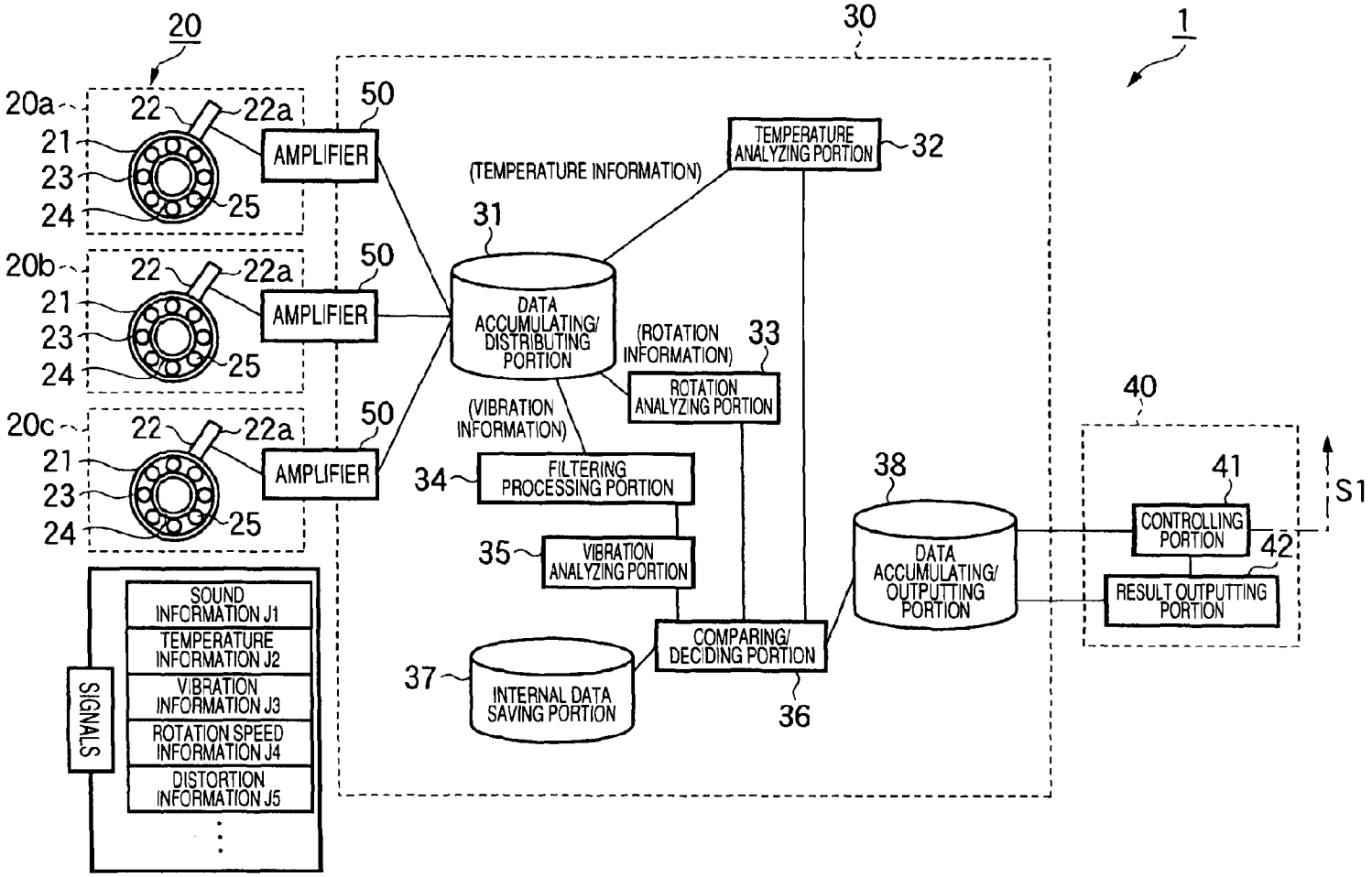
57. A bearing unit according to any one of claims 53 to 56, wherein a case of the abnormality sensing means has a signal carrying means that sends out a sensed signal, and a decision result outputting portion that decides a presence or absence of the abnormality based on the signal sent out via the signal carrying means and output a decision result.

58. A bearing unit according to any one of claims 53 to 57, wherein the abnormality sensing means is embedded/fixed on a recess portion formed on the bearing housing, and then secured by molding a clearance between the abnormality sensing means and the recess portion.

59. A bearing unit according to claim 58, wherein the abnormality sensing means is fixed to the recess portion via a spacer.

60. A bearing unit according to any one of claims 53 to 59, wherein a filtering processing portion for removing an unnecessary frequency band from a vibration waveform from the vibration sensor, an envelope processing portion for detecting an absolute value of a filtered waveform transferred from the filtering processing portion, a frequency analyzing portion for analyzing a frequency of a waveform transferred from the envelope processing portion, a comparing/collating portion for comparing a frequency generated due to a damage calculated based on a rotation speed with a frequency derived based on actually measured data, and a result outputting portion for identifying a presence or absence of the abnormality and an abnormal location based on a compared result in the comparing/collating portion are provided.

FIG. 1



EP 1 548 419 A1

FIG. 2(a)

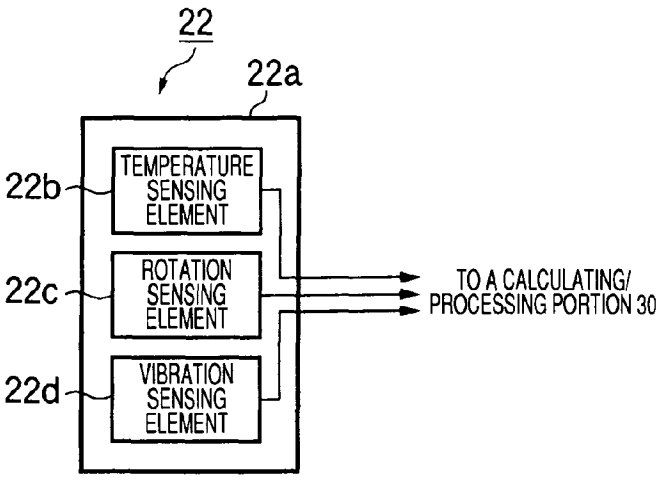

22
22a
22b
TEMPERATURE SENSING ELEMENT
22c
ROTATION SENSING ELEMENT
22d
VIBRATION SENSING ELEMENT
TO A CALCULATING/ PROCESSING PORTION 30

FIG. 2(b)

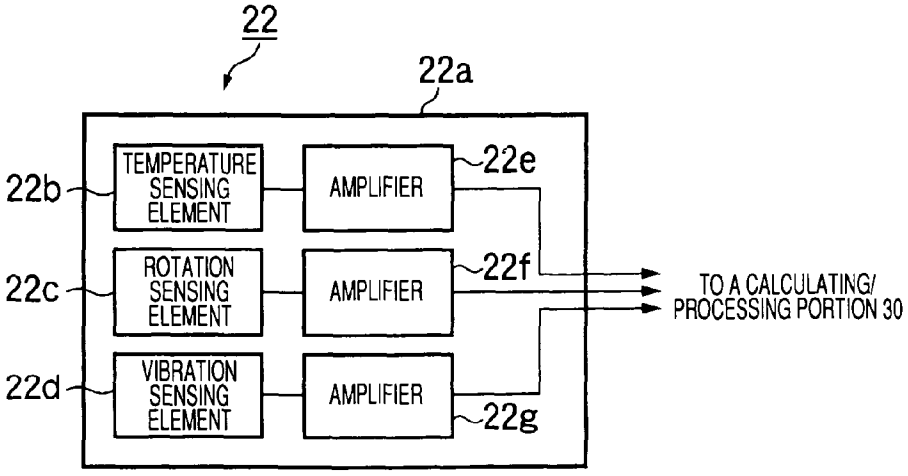

22
22a
22b
TEMPERATURE SENSING ELEMENT
AMPLIFIER
22e
22c
ROTATION SENSING ELEMENT
AMPLIFIER
22f
22d
VIBRATION SENSING ELEMENT
AMPLIFIER
22g
TO A CALCULATING/ PROCESSING PORTION 30

FIG. 3

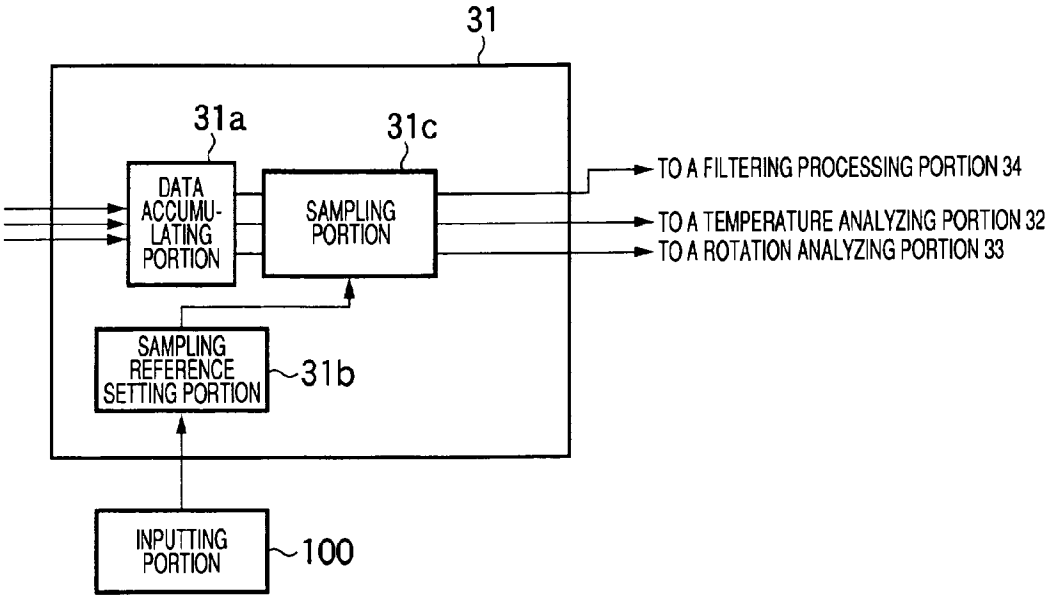

31
31a
31c
DATA ACCUMU-LATING PORTION
SAMPLING PORTION
TO A FILTERING PROCESSING PORTION 34
TO A TEMPERATURE ANALYZING PORTION 32
TO A ROTATION ANALYZING PORTION 33
SAMPLING REFERENCE SETTING PORTION
31b
INPUTTING PORTION
100

FIG. 4

FLAW OF A ROLLING BEARING	FREQUENCY AFTER AN ENVELOPING PROCESS
INNER RING (Si)	$Zfi=\frac{fr}{2}\left(1+\frac{Da}{dm}\cos\alpha\right)Z$ [Hz]
OUTER RING (So)	$Zfc=\frac{fr}{2}\left(1-\frac{Da}{dm}\cos\alpha\right)Z$ [Hz]
ROLLING ELEMENT (Sb)	$2fb=fr\left(1-\frac{Da^2}{dm^2}\cos^2\alpha\right)$ [Hz]
RETAINER (Sc)	$fc=\frac{fr}{2}\left(1-\frac{Da}{dm}\cos\alpha\right)$ [Hz]

fr: INNER RING ROTATION SPEED [Hz]
fc: RETAINER ROTATION SPEED [Hz]
fb: ROLLING ELEMENT ROTATION SPEED [Hz]
dm: PITCH CIRCLE DIAMETER [mm]
Z: NUMBER OF ROLLING ELEMENTS
fi: fr-fc
Da: ROLLING ELEMENT DIAMETER [mm]
α: CONTACT ANGLE [DEGREE]

FIG. 5

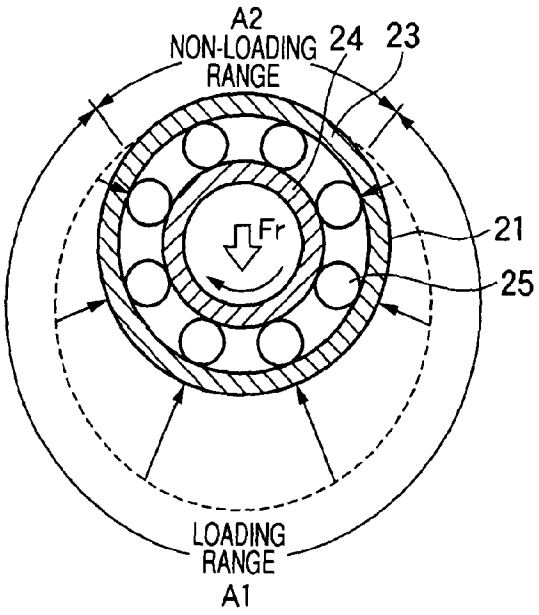


FIG. 6

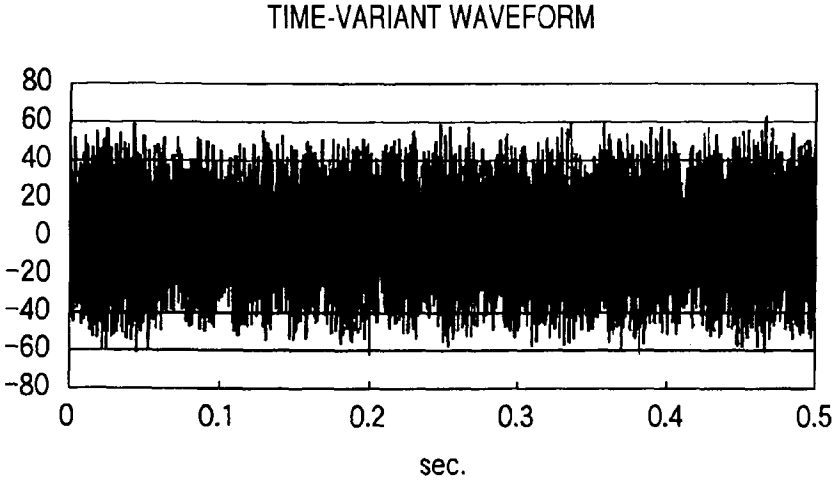

TIME-VARIANT WAVEFORM
80
60
40
20
0
-20
-40
-60
-80
0
0.1
0.2
0.3
0.4
0.5
sec.

FIG. 7

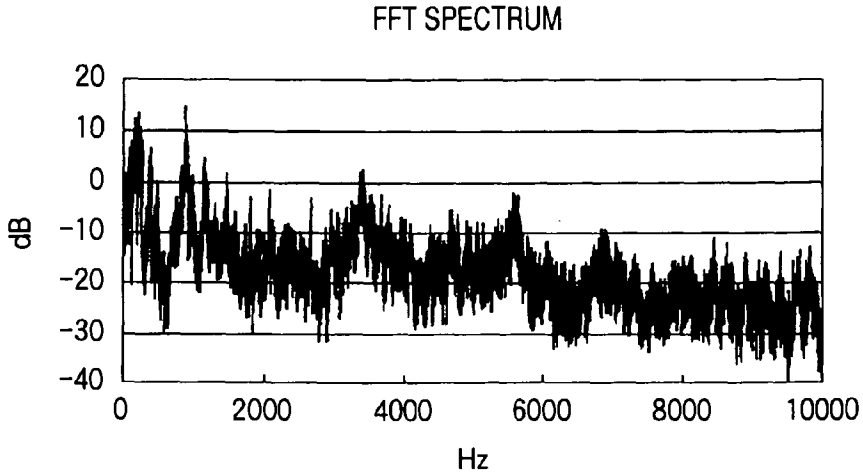

FFT SPECTRUM
20
10
0
-10
-20
-30
-40
dB
0
2000
4000
6000
8000
10000
Hz

FIG. 8

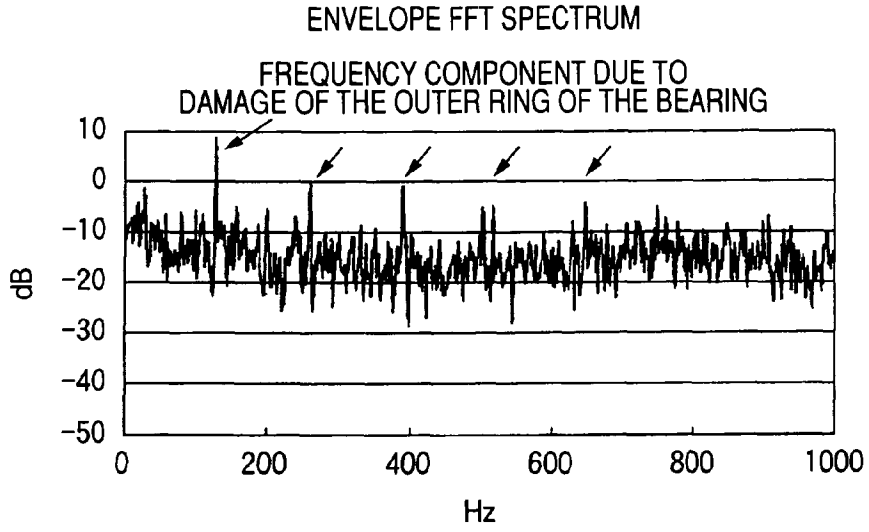

ENVELOPE FFT SPECTRUM
FREQUENCY COMPONENT DUE TO
DAMAGE OF THE OUTER RING OF THE BEARING
10
0
-10
-20
-30
-40
-50
dB
0
200
400
600
800
1000
Hz

FIG. 9

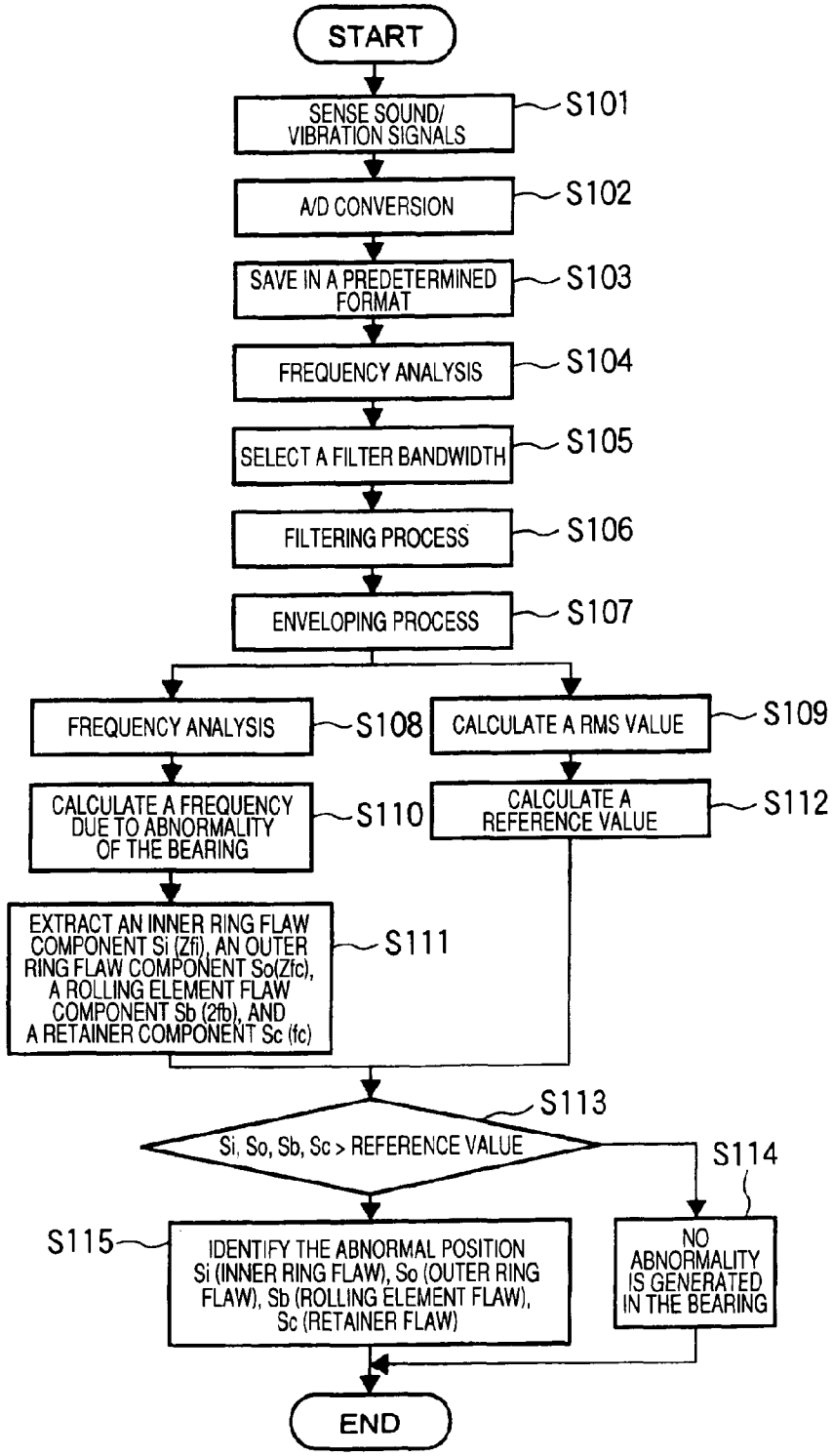

START
SENSE SOUND/ VIBRATION SIGNALS
S101
A/D CONVERSION
S102
SAVE IN A PREDETERMINED FORMAT
S103
FREQUENCY ANALYSIS
S104
SELECT A FILTER BANDWIDTH
S105
FILTERING PROCESS
S106
ENVELOPING PROCESS
S107
FREQUENCY ANALYSIS
S108
CALCULATE A RMS VALUE
S109
CALCULATE A FREQUENCY DUE TO ABNORMALITY OF THE BEARING
S110
CALCULATE A REFERENCE VALUE
S112
EXTRACT AN INNER RING FLAW COMPONENT Si (Zfi), AN OUTER RING FLAW COMPONENT So(Zfc), A ROLLING ELEMENT FLAW COMPONENT Sb (2fb), AND A RETAINER COMPONENT Sc (fc)
S111
S113
Si, So, Sb, Sc > REFERENCE VALUE
S114
S115
IDENTIFY THE ABNORMAL POSITION Si (INNER RING FLAW), So (OUTER RING FLAW), Sb (ROLLING ELEMENT FLAW), Sc (RETAINER FLAW)
NO ABNORMALITY IS GENERATED IN THE BEARING
END

FIG. 10

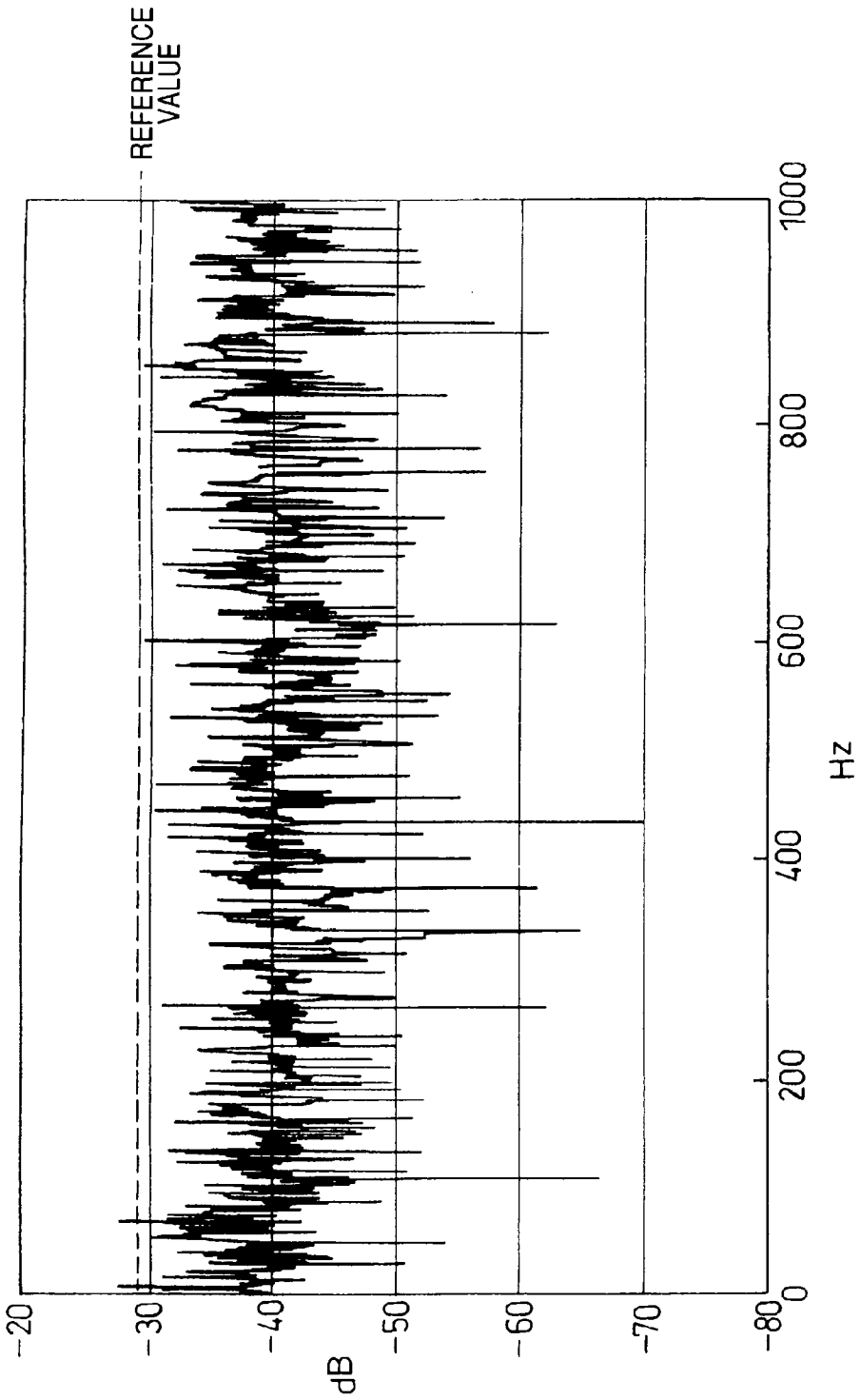


FIG. 11

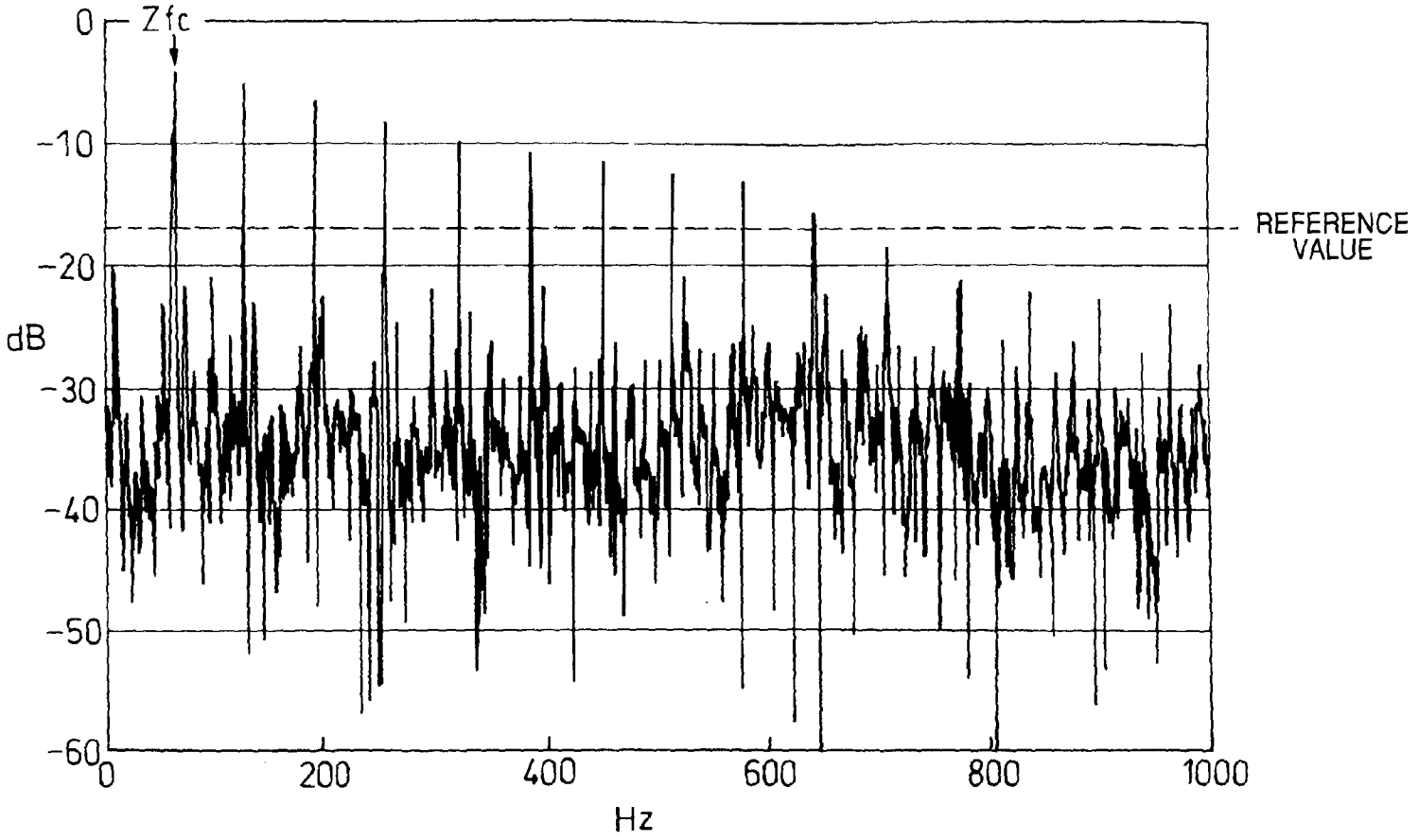

0
Zfc
-10
-20
dB
-30
-40
-50
-60
0
200
400
600
800
1000
Hz
REFERENCE VALUE

FIG. 12

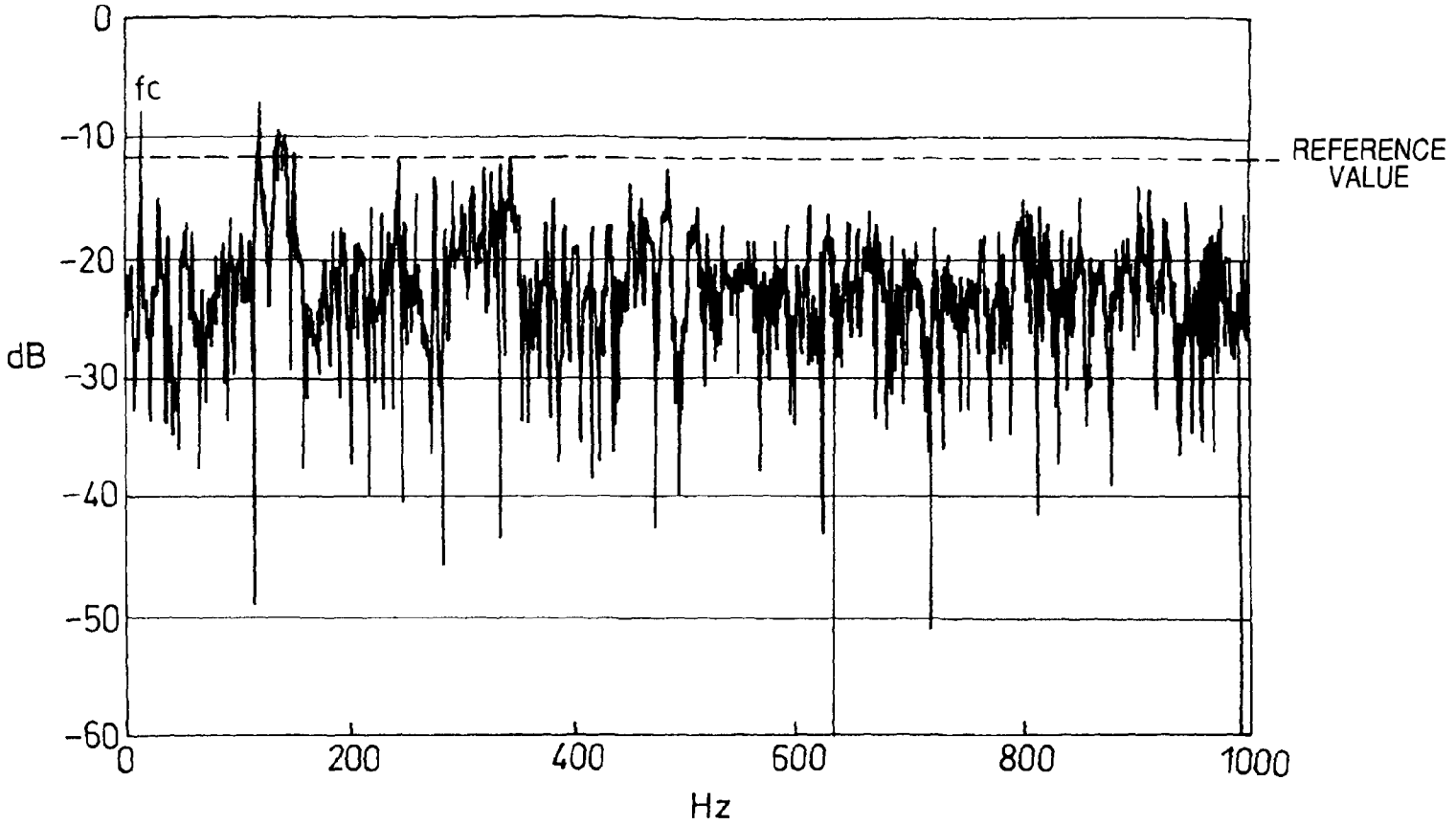

0
fc
-10
-20
-30
-40
-50
-60
dB
REFERENCE VALUE
0
200
400
600
800
1000
Hz

FIG. 13

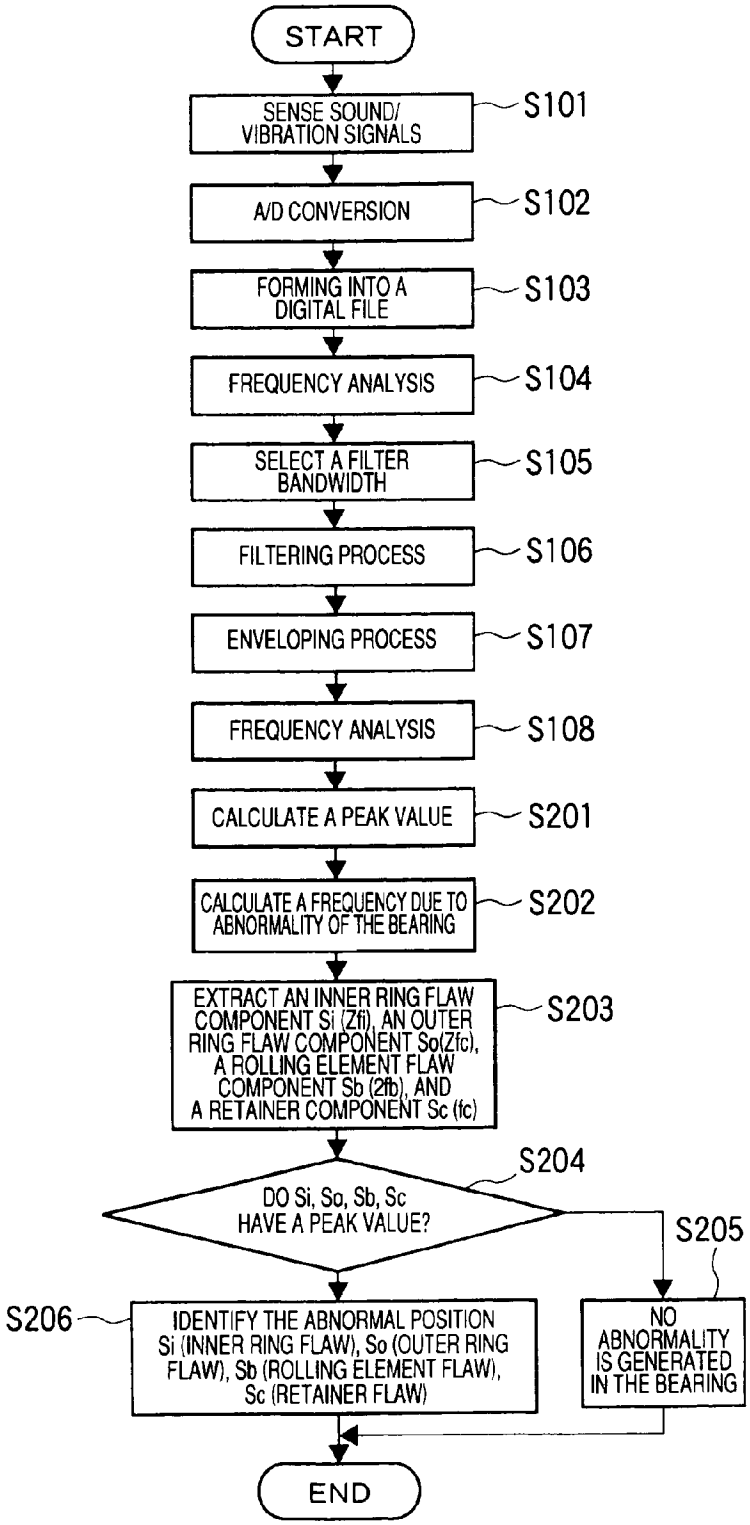
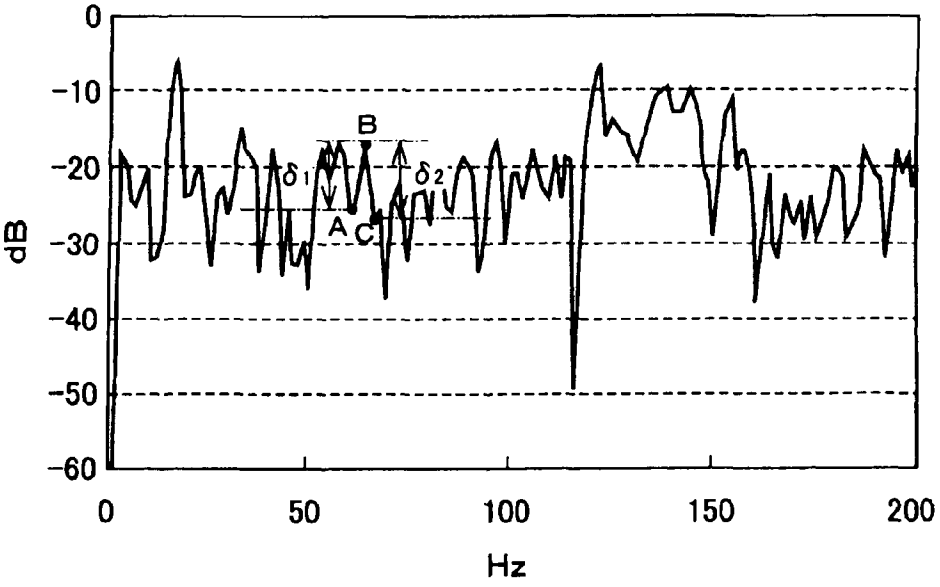

START
SENSE SOUND/ VIBRATION SIGNALS
S101
A/D CONVERSION
S102
FORMING INTO A DIGITAL FILE
S103
FREQUENCY ANALYSIS
S104
SELECT A FILTER BANDWIDTH
S105
FILTERING PROCESS
S106
ENVELOPING PROCESS
S107
FREQUENCY ANALYSIS
S108
CALCULATE A PEAK VALUE
S201
CALCULATE A FREQUENCY DUE TO ABNORMALITY OF THE BEARING
S202
EXTRACT AN INNER RING FLAW COMPONENT Si (Zfi), AN OUTER RING FLAW COMPONENT So(Zfc), A ROLLING ELEMENT FLAW COMPONENT Sb (2fb), AND A RETAINER COMPONENT Sc (fc)
S203
DO Si, So, Sb, Sc HAVE A PEAK VALUE?
S204
S205
S206
IDENTIFY THE ABNORMAL POSITION Si (INNER RING FLAW), So (OUTER RING FLAW), Sb (ROLLING ELEMENT FLAW), Sc (RETAINER FLAW)
NO ABNORMALITY IS GENERATED IN THE BEARING
END

FIG. 14



$\delta_1(=Y_1-Y_0)>0$ - (1)
$\delta_2(=Y_2-Y_1)<0$ - (2)
WHERE A (X_0,Y_0), B (X_1,Y_1), C (X_2,Y_2).
WHEN (1), (2) ARE SATISFIED AND
$dy/dx=(Y_1-Y_0)/(X_1-X_0)>1$
OR
$dy/dx=(Y_2-Y_1)/(X_2-X_1)<-1$
IS SATISFIED, Y_1 IS DECIDED AS A PEAK.

FIG. 15

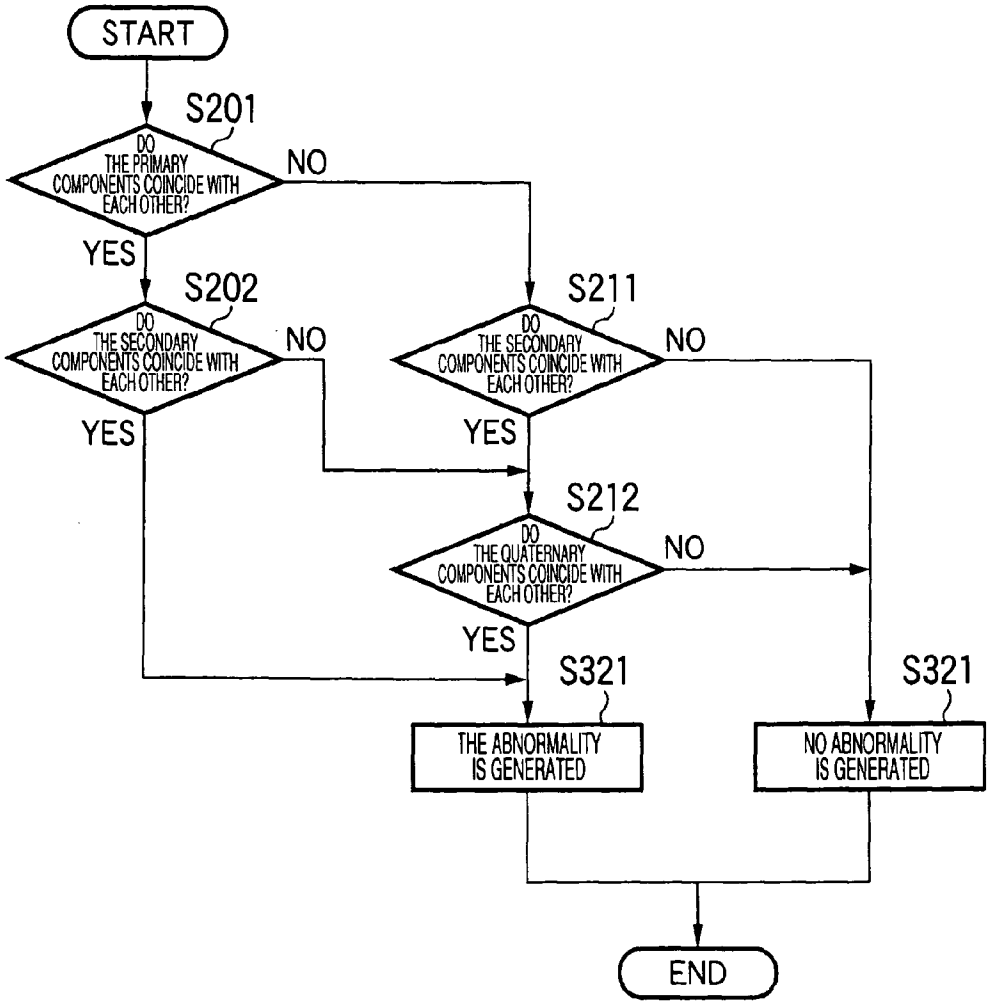
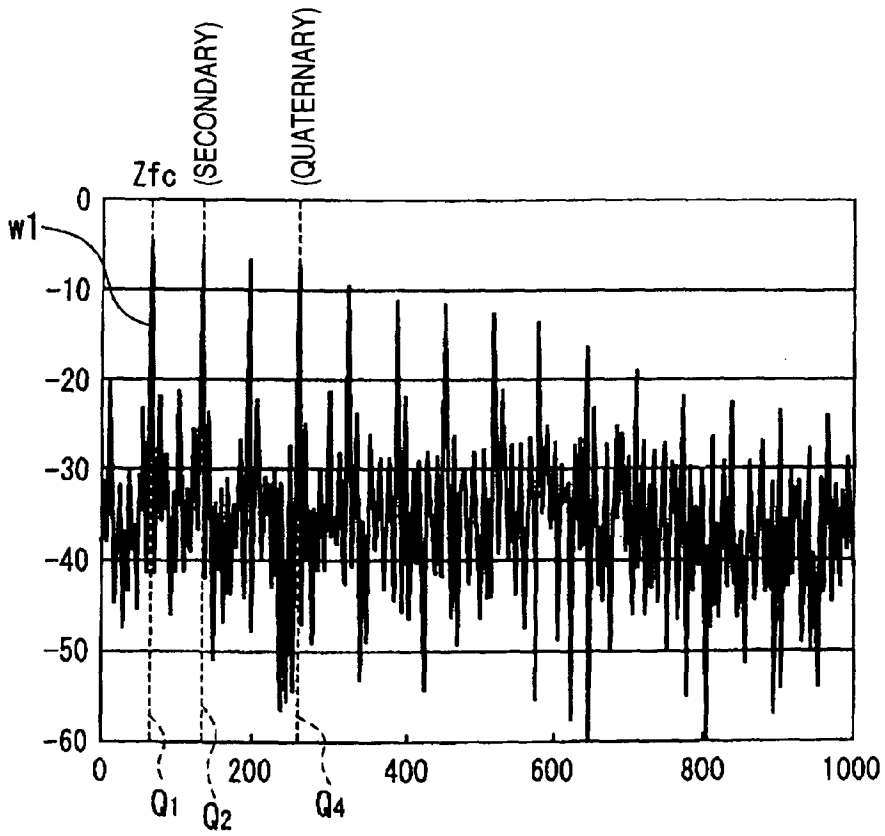

START
S201
DO THE PRIMARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S202
DO THE SECONDARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S211
DO THE SECONDARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S212
DO THE QUATERNARY COMPONENTS COINCIDE WITH EACH OTHER?
NO
YES
S321
THE ABNORMALITY IS GENERATED
S321
NO ABNORMALITY IS GENERATED
END

FIG. 16



COLLATE ONLY THE PRIMARY, SECONDARY, QUATERNARY COMPONENTS (FLAW OF THE OUTER RING)

FIG. 17

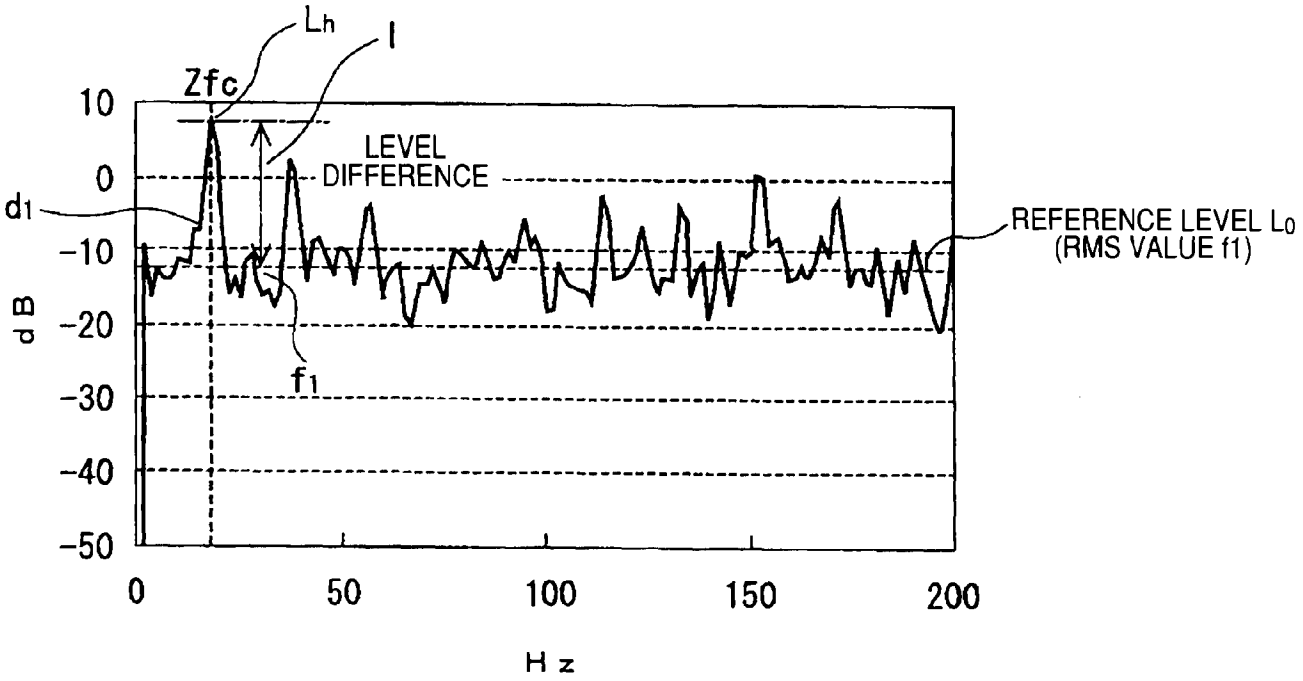
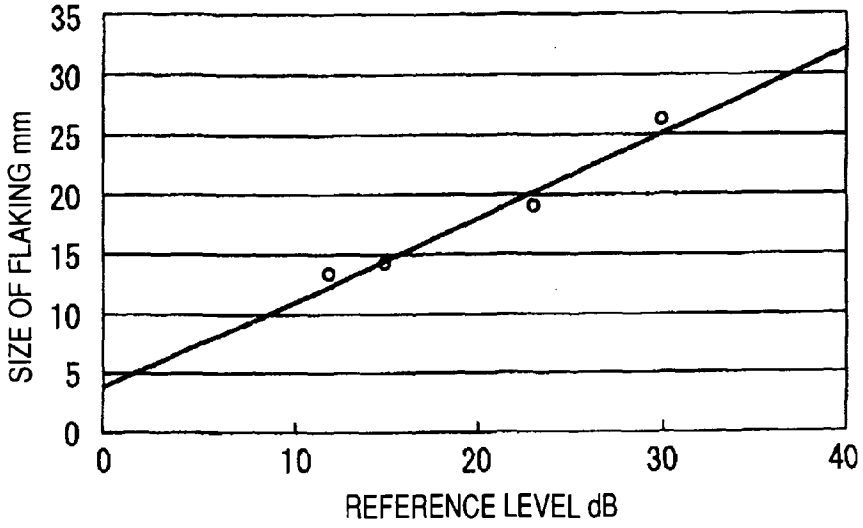

Lh
l
Zfc
10
0
LEVEL
DIFFERENCE
d1
REFERENCE LEVEL L0
(RMS VALUE f1)
-10
dB
-20
f1
-30
-40
-50
0
50
100
150
200
Hz

FIG. 18



A RELATIONSHIP BETWEEN A SIZE OF FLAKING AND A LEVEL DIFFERENCE

FIG. 19

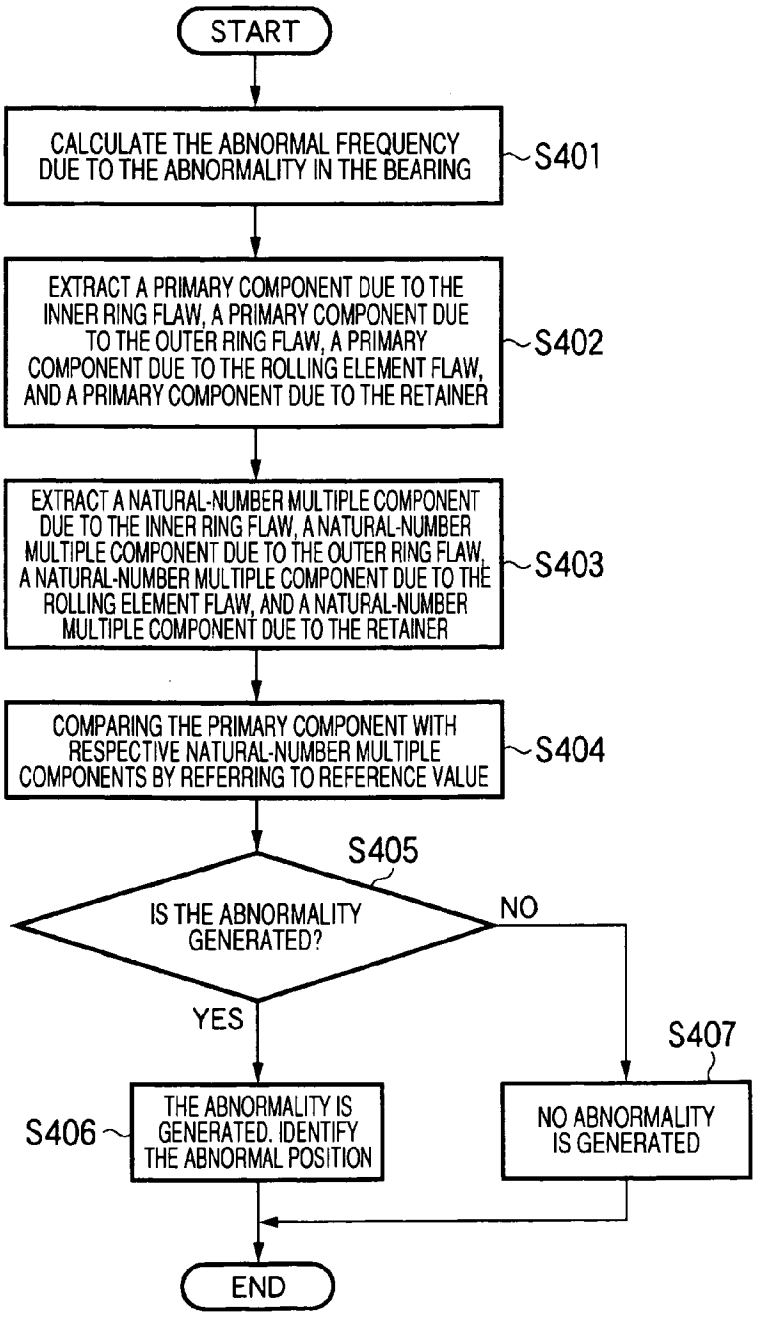

START
CALCULATE THE ABNORMAL FREQUENCY DUE TO THE ABNORMALITY IN THE BEARING
S401
EXTRACT A PRIMARY COMPONENT DUE TO THE INNER RING FLAW, A PRIMARY COMPONENT DUE TO THE OUTER RING FLAW, A PRIMARY COMPONENT DUE TO THE ROLLING ELEMENT FLAW, AND A PRIMARY COMPONENT DUE TO THE RETAINER
S402
EXTRACT A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE INNER RING FLAW, A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE OUTER RING FLAW, A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE ROLLING ELEMENT FLAW, AND A NATURAL-NUMBER MULTIPLE COMPONENT DUE TO THE RETAINER
S403
COMPARING THE PRIMARY COMPONENT WITH RESPECTIVE NATURAL-NUMBER MULTIPLE COMPONENTS BY REFERRING TO REFERENCE VALUE
S404
S405
IS THE ABNORMALITY GENERATED?
NO
YES
S407
S406
THE ABNORMALITY IS GENERATED. IDENTIFY THE ABNORMAL POSITION
NO ABNORMALITY IS GENERATED
END

FIG. 20

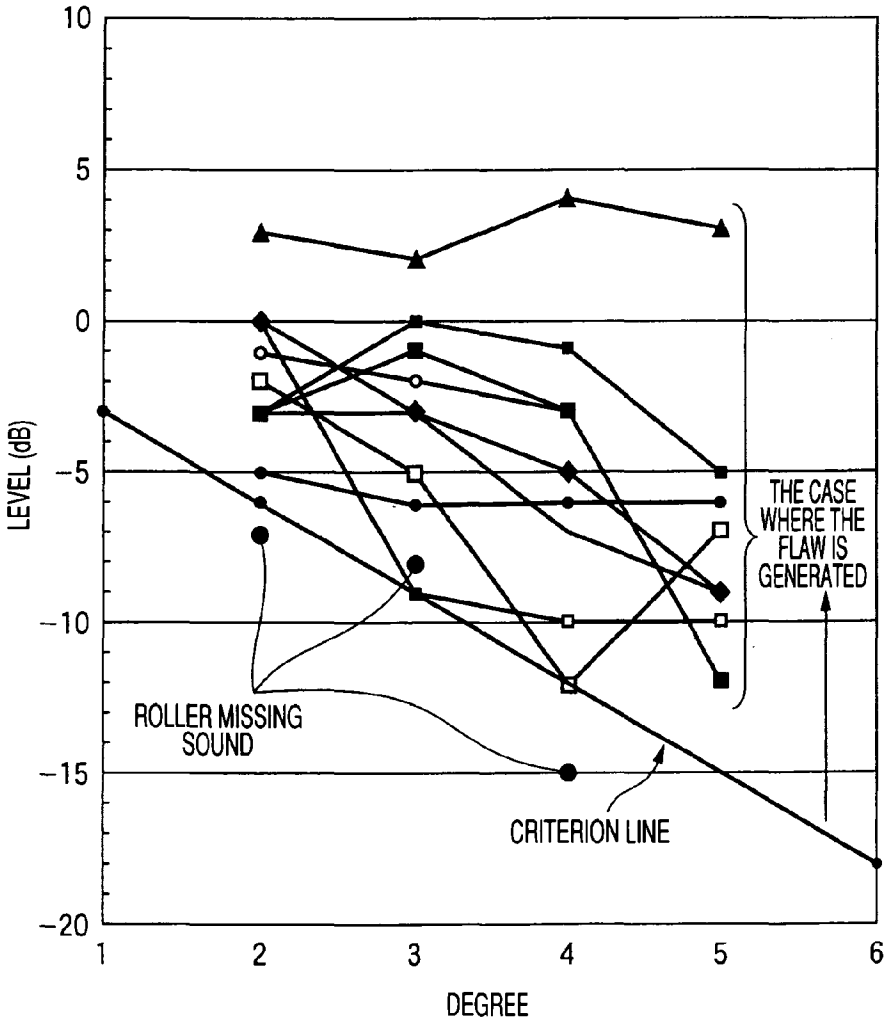

10
5
0
−5
−10
−15
−20
LEVEL (dB)
1
2
3
4
5
6
DEGREE
THE CASE WHERE THE FLAW IS GENERATED
ROLLER MISSING SOUND
CRITERION LINE

FIG. 21

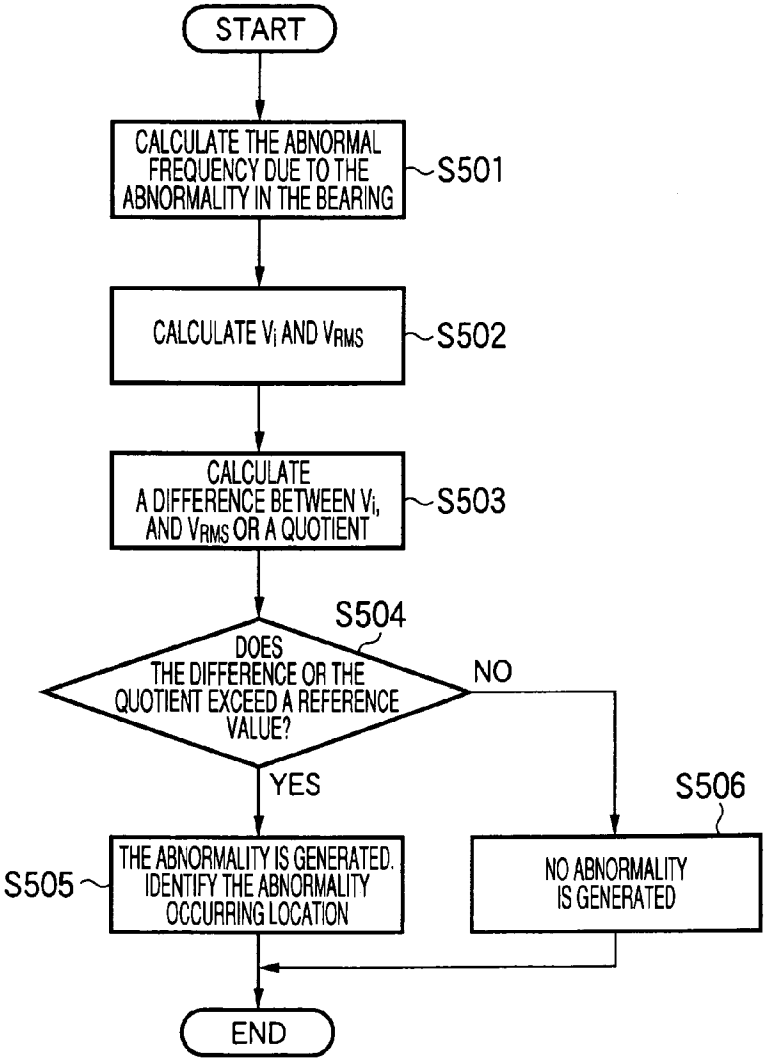

START
CALCULATE THE ABNORMAL FREQUENCY DUE TO THE ABNORMALITY IN THE BEARING
S501
CALCULATE Vi AND VRMS
S502
CALCULATE A DIFFERENCE BETWEEN Vi, AND VRMS OR A QUOTIENT
S503
S504
DOES THE DIFFERENCE OR THE QUOTIENT EXCEED A REFERENCE VALUE?
NO
YES
S506
S505
THE ABNORMALITY IS GENERATED. IDENTIFY THE ABNORMALITY OCCURRING LOCATION
NO ABNORMALITY IS GENERATED
END

FIG. 22

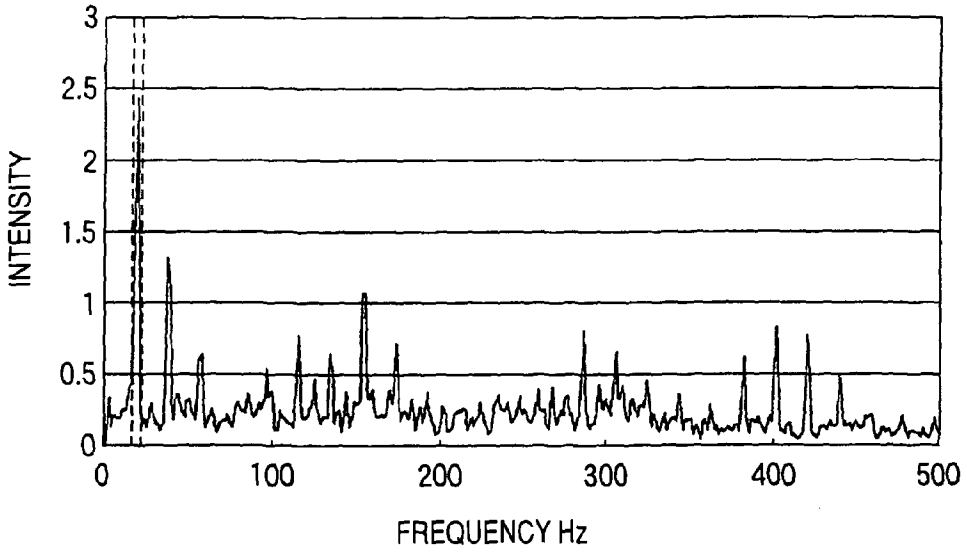

INTENSITY
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 23

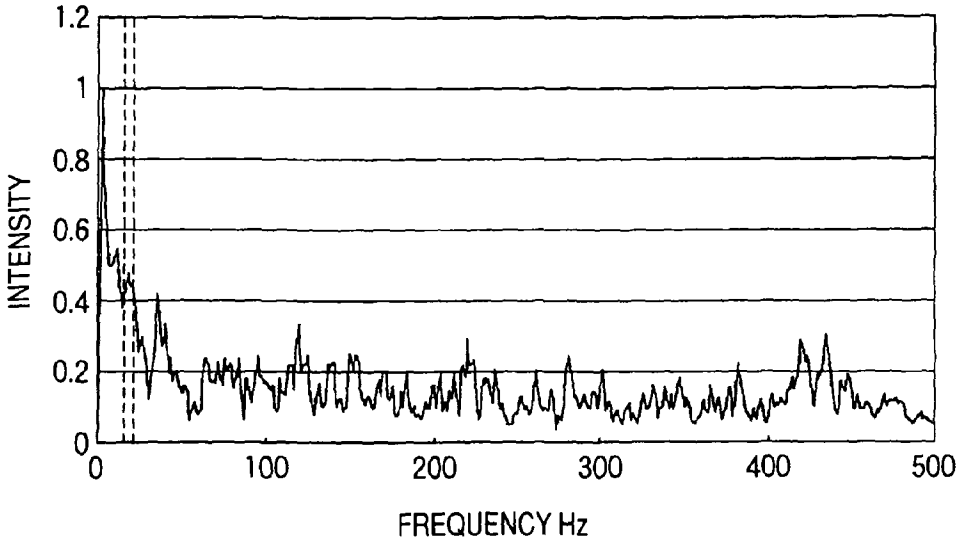

INTENSITY
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 24

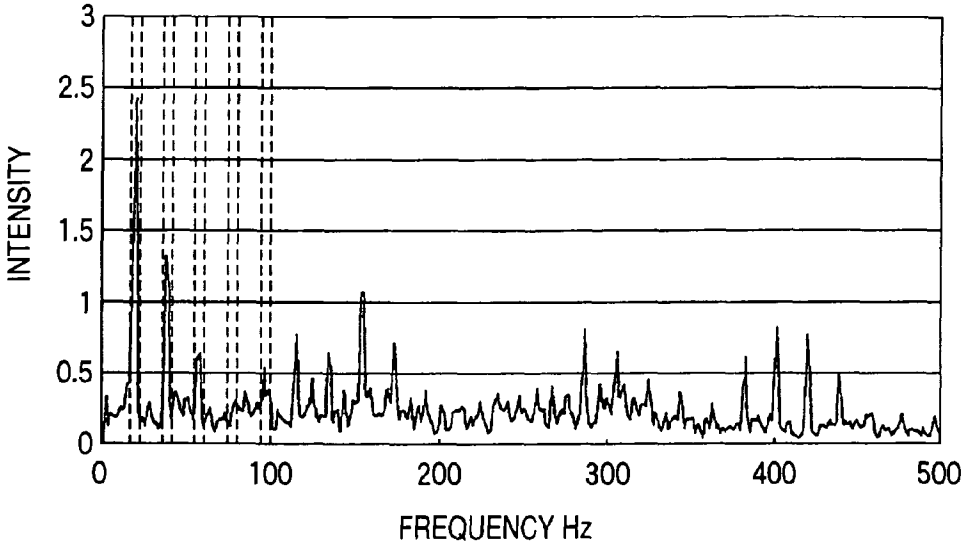

INTENSITY
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 25

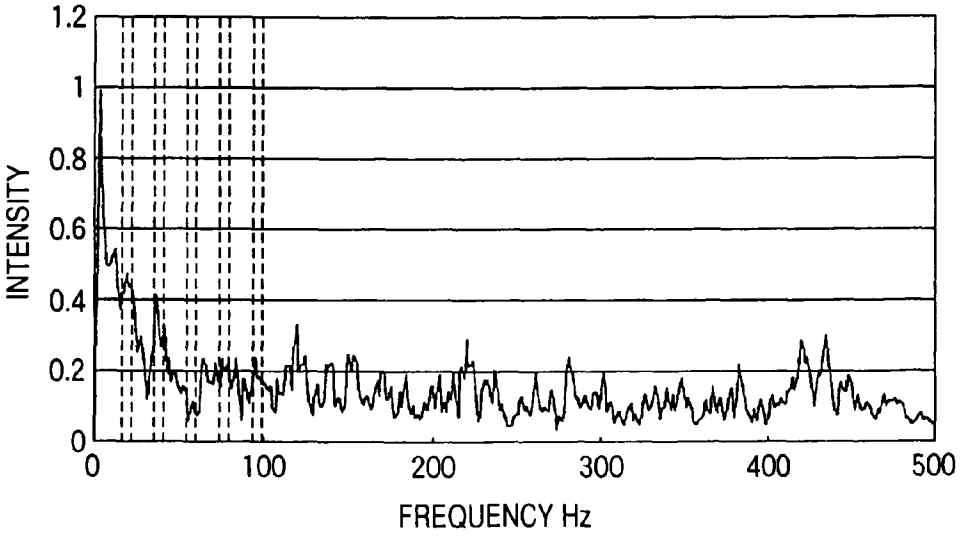

INTENSITY
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
FREQUENCY Hz

FIG. 26

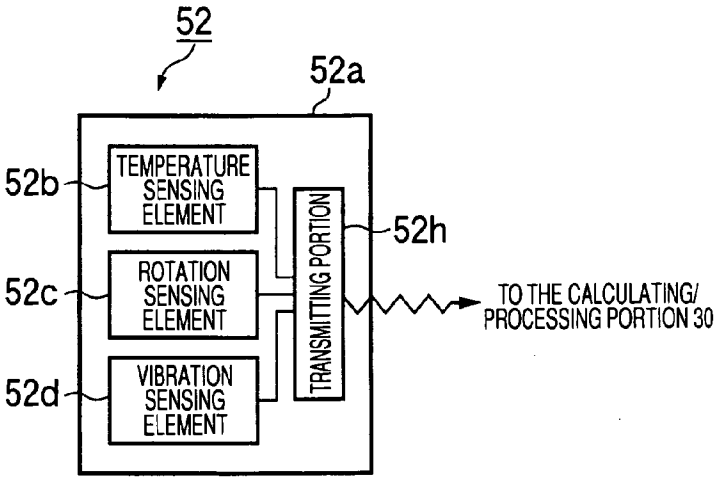

52
52a
52b
TEMPERATURE SENSING ELEMENT
52c
ROTATION SENSING ELEMENT
52d
VIBRATION SENSING ELEMENT
TRANSMITTING PORTION
52h
TO THE CALCULATING/ PROCESSING PORTION 30

FIG. 27

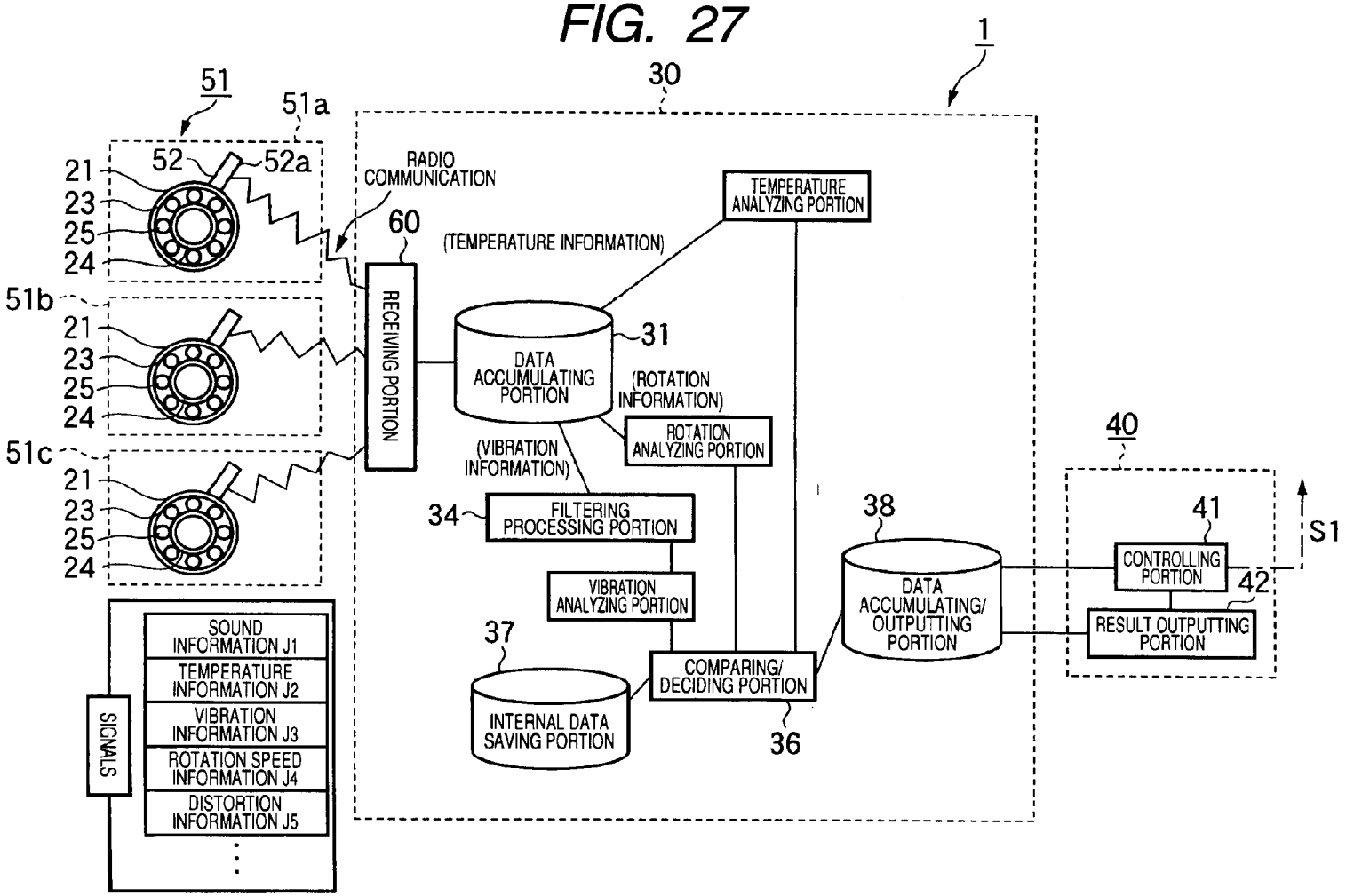

1
30
51
51a
52
52a
21
23
25
24
51b
51c
RADIO COMMUNICATION
60
RECEIVING PORTION
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
DATA ACCUMULATING PORTION
31
(ROTATION INFORMATION)
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
VIBRATION ANALYZING PORTION
37
INTERNAL DATA SAVING PORTION
COMPARING/ DECIDING PORTION
36
38
DATA ACCUMULATING/ OUTPUTTING PORTION
40
41
CONTROLLING PORTION
42
RESULT OUTPUTTING PORTION
S1
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 28

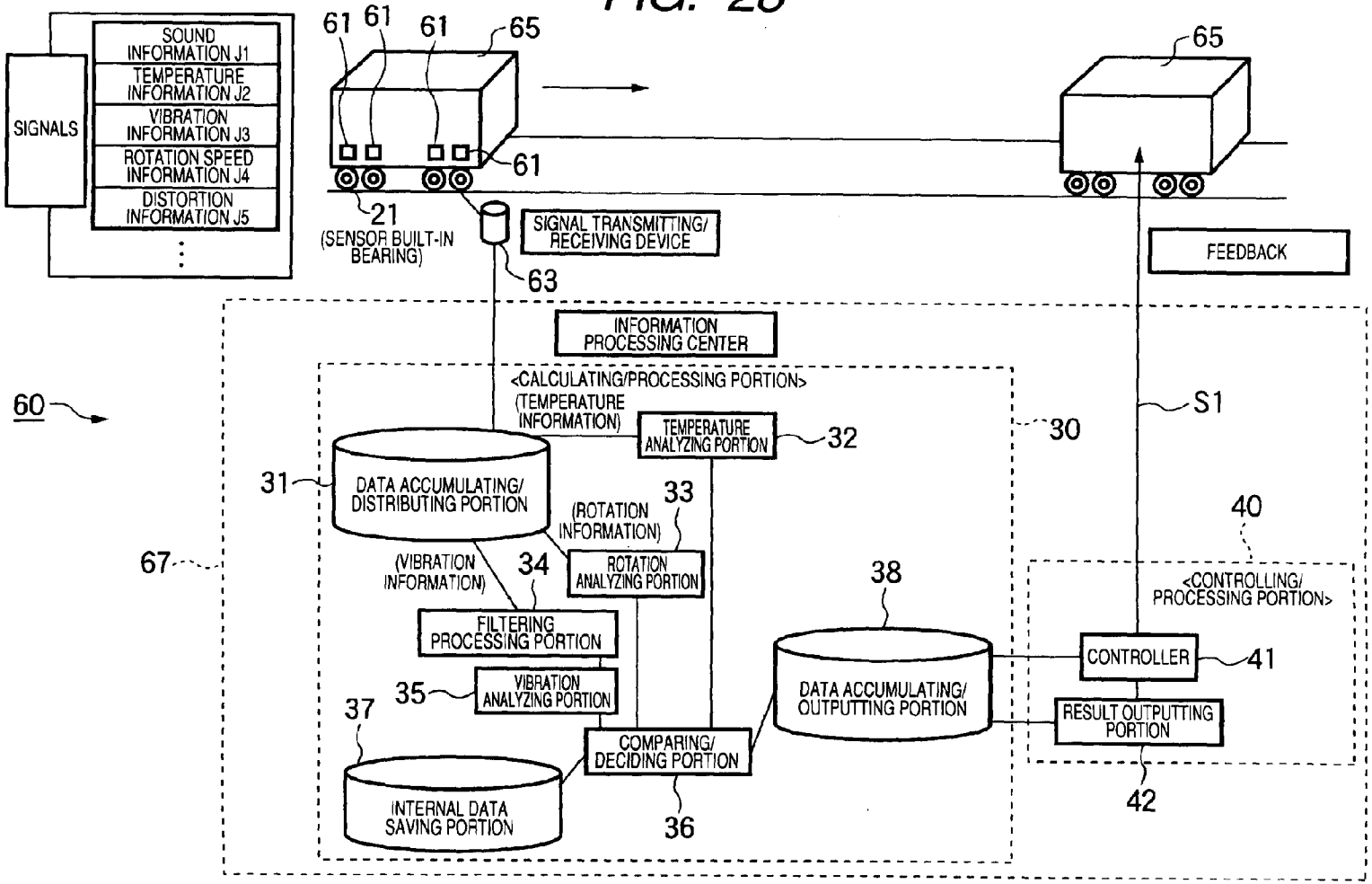

SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5
61
61
61
65
65
61
21
(SENSOR BUILT-IN BEARING)
SIGNAL TRANSMITTING/ RECEIVING DEVICE
63
FEEDBACK
INFORMATION PROCESSING CENTER
60
<CALCULATING/PROCESSING PORTION>
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
32
30
S1
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
33
(ROTATION INFORMATION)
40
67
(VIBRATION INFORMATION)
34
ROTATION ANALYZING PORTION
38
<CONTROLLING/ PROCESSING PORTION>
FILTERING PROCESSING PORTION
CONTROLLER
41
35
VIBRATION ANALYZING PORTION
DATA ACCUMULATING/ OUTPUTTING PORTION
37
RESULT OUTPUTTING PORTION
COMPARING/ DECIDING PORTION
INTERNAL DATA SAVING PORTION
36
42

FIG. 29

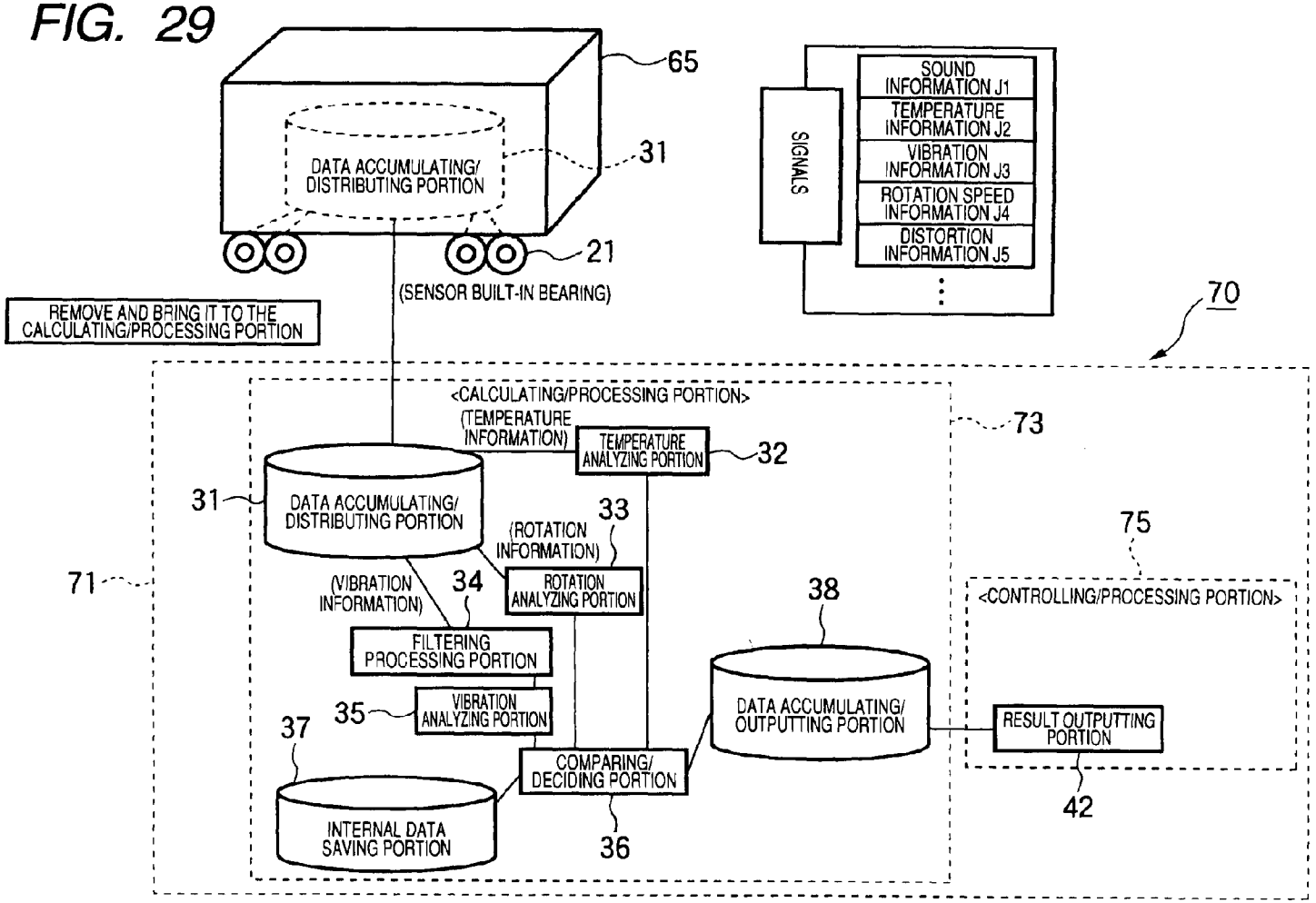

65
DATA ACCUMULATING/ DISTRIBUTING PORTION
31
21
(SENSOR BUILT-IN BEARING)
REMOVE AND BRING IT TO THE CALCULATING/PROCESSING PORTION
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5
70
<CALCULATING/PROCESSING PORTION>
73
(TEMPERATURE INFORMATION)
TEMPERATURE ANALYZING PORTION
32
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
33
(ROTATION INFORMATION)
71
(VIBRATION INFORMATION)
34
ROTATION ANALYZING PORTION
38
FILTERING PROCESSING PORTION
VIBRATION ANALYZING PORTION
35
37
DATA ACCUMULATING/ OUTPUTTING PORTION
75
<CONTROLLING/PROCESSING PORTION>
RESULT OUTPUTTING PORTION
42
COMPARING/ DECIDING PORTION
INTERNAL DATA SAVING PORTION
36

FIG. 30

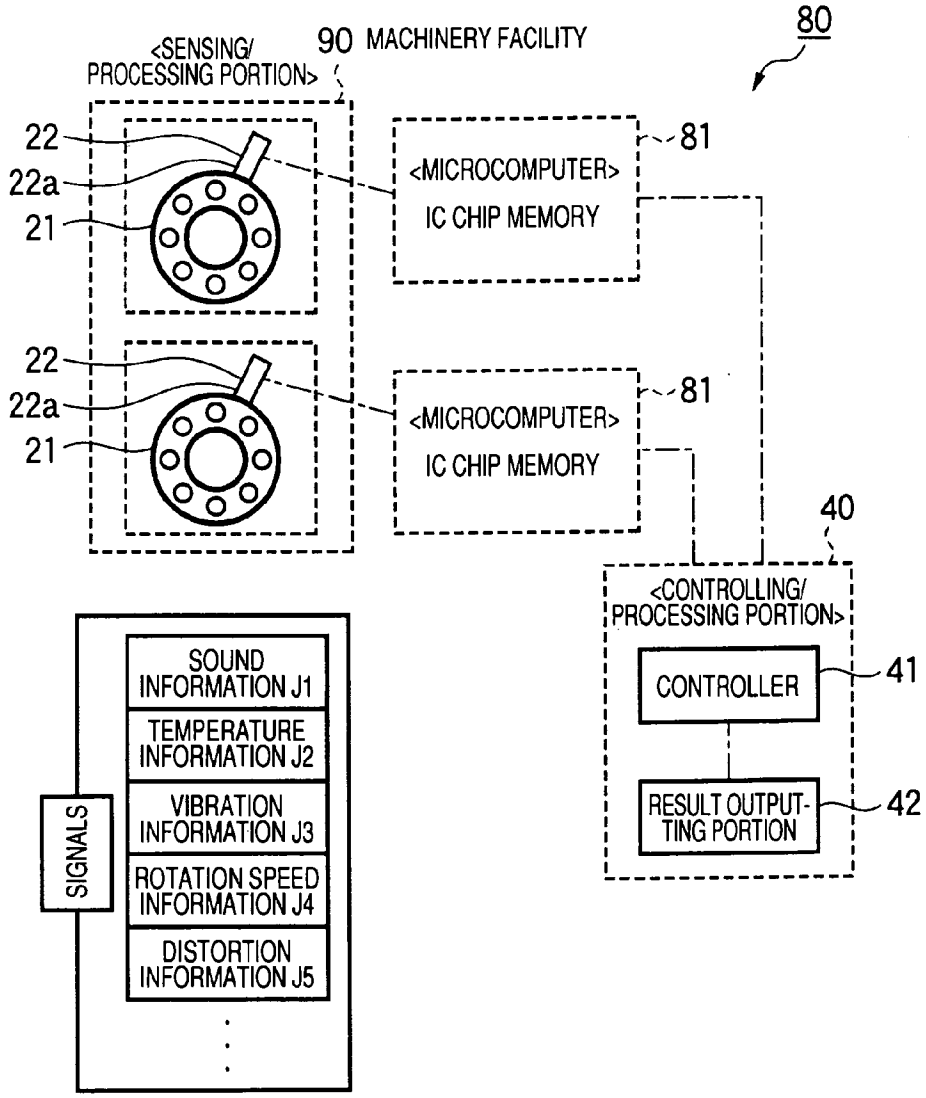

80
90 MACHINERY FACILITY
<SENSING/ PROCESSING PORTION>
22
22a
21
22
22a
21
<MICROCOMPUTER>
IC CHIP MEMORY
81
<MICROCOMPUTER>
IC CHIP MEMORY
81
40
<CONTROLLING/ PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUT-TING PORTION
42
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 31

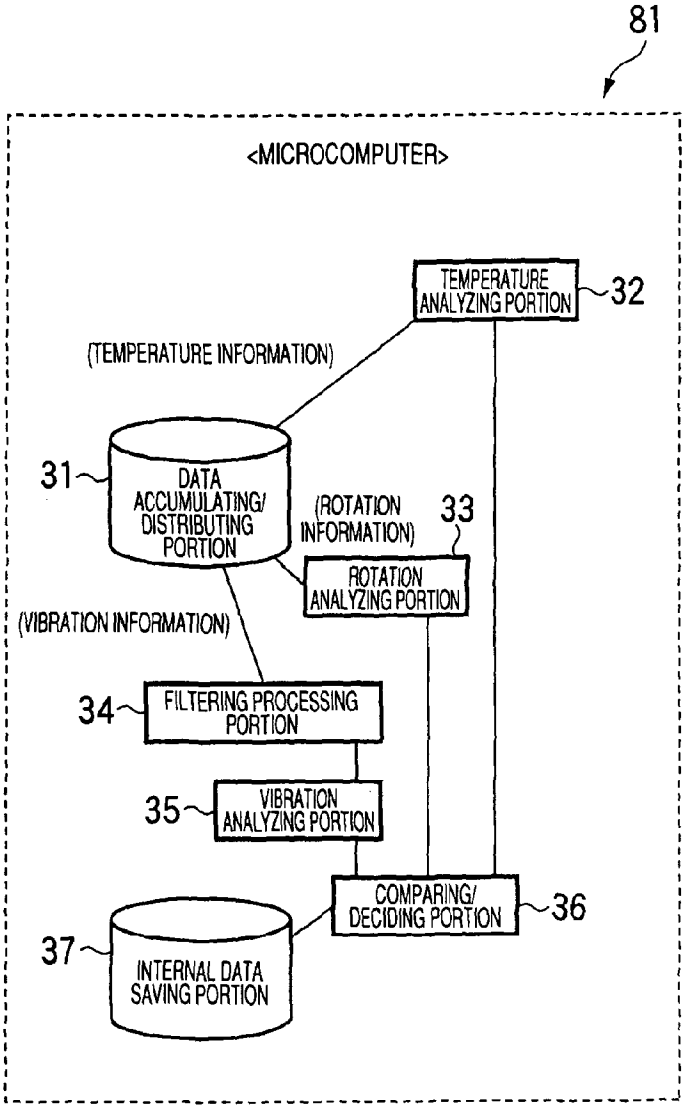

81
<MICROCOMPUTER>
TEMPERATURE ANALYZING PORTION
32
(TEMPERATURE INFORMATION)
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
(ROTATION INFORMATION)
33
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
35
VIBRATION ANALYZING PORTION
COMPARING/ DECIDING PORTION
36
37
INTERNAL DATA SAVING PORTION

FIG. 32

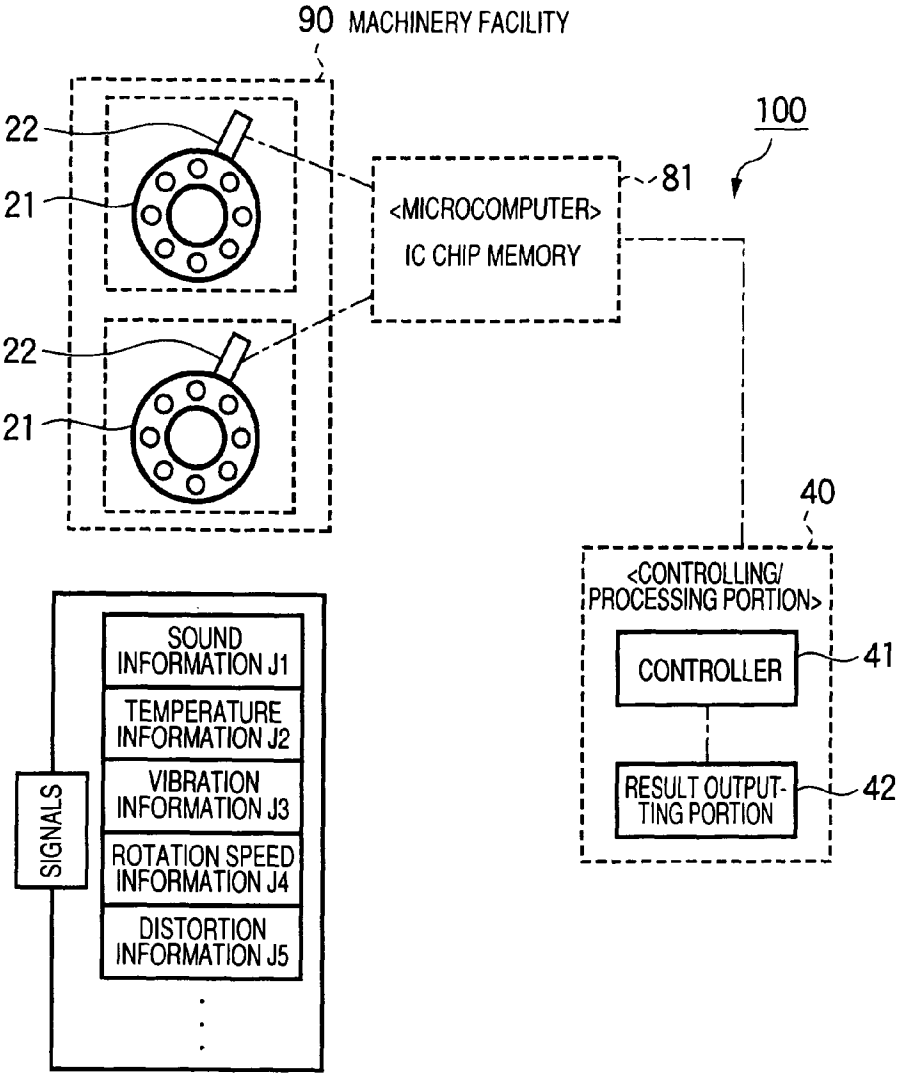

90 MACHINERY FACILITY
22
21
22
21
100
81
<MICROCOMPUTER>
IC CHIP MEMORY
40
<CONTROLLING/
PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUT-
TING PORTION
42
SIGNALS
SOUND
INFORMATION J1
TEMPERATURE
INFORMATION J2
VIBRATION
INFORMATION J3
ROTATION SPEED
INFORMATION J4
DISTORTION
INFORMATION J5

FIG. 33

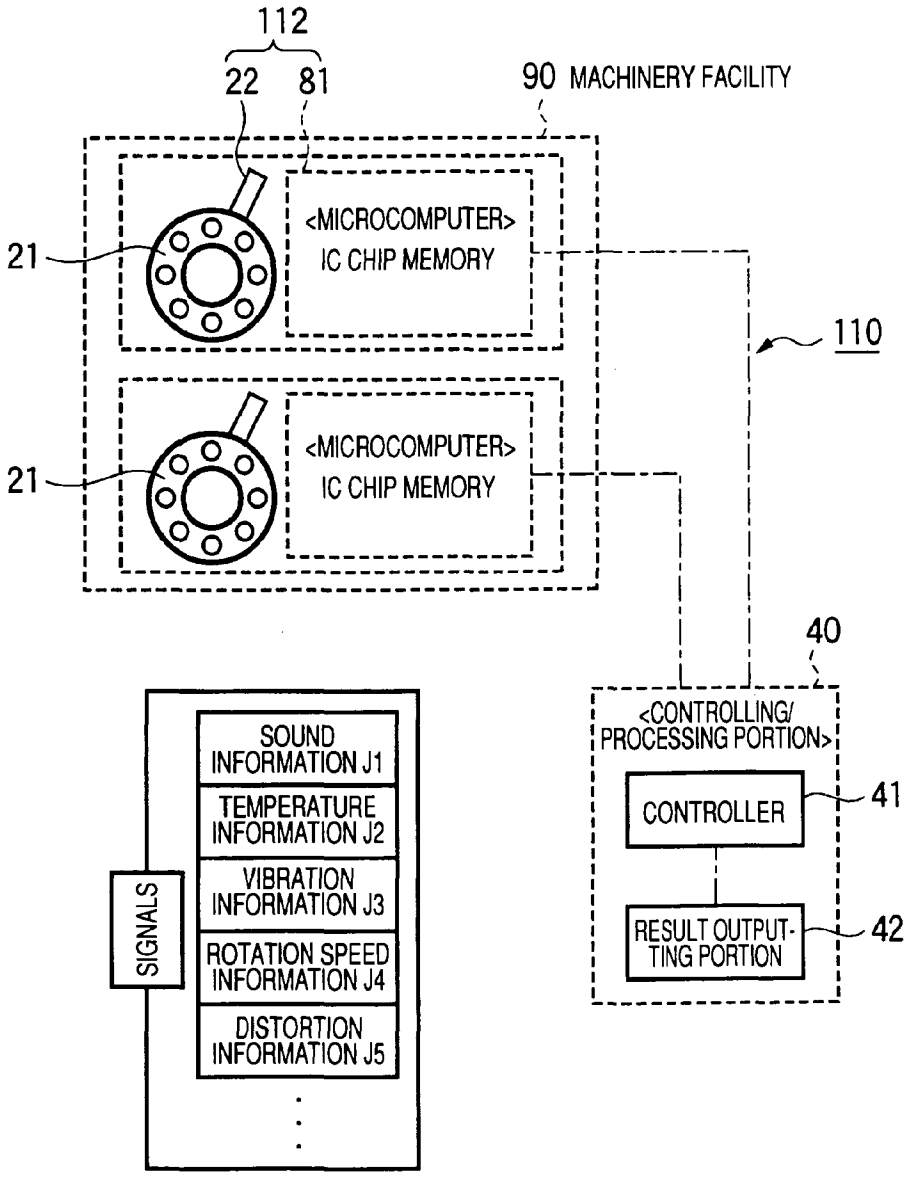

112
22
81
90 MACHINERY FACILITY
21
<MICROCOMPUTER>
IC CHIP MEMORY
21
<MICROCOMPUTER>
IC CHIP MEMORY
110
40
<CONTROLLING/
PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUT-
TING PORTION
42
SIGNALS
SOUND
INFORMATION J1
TEMPERATURE
INFORMATION J2
VIBRATION
INFORMATION J3
ROTATION SPEED
INFORMATION J4
DISTORTION
INFORMATION J5

FIG. 34(a)

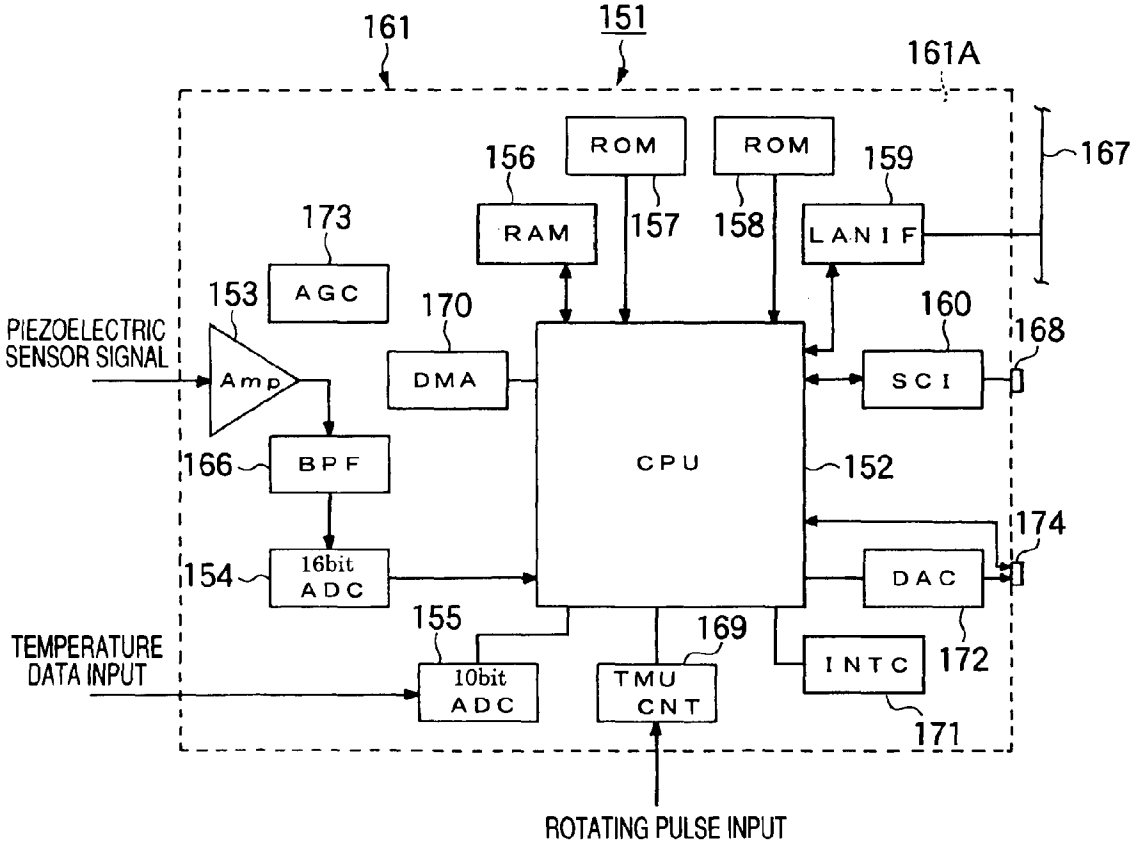
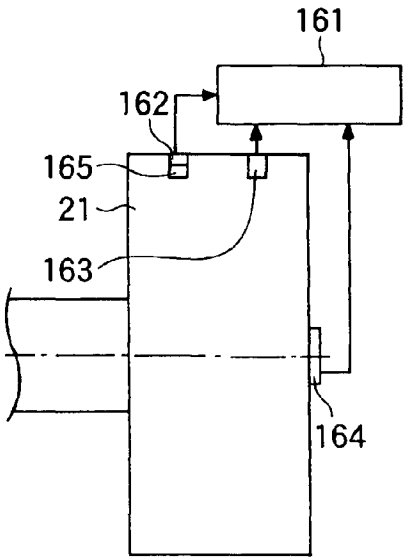


FIG. 34(b)



EP 1 548 419 A1

FIG. 35(a)

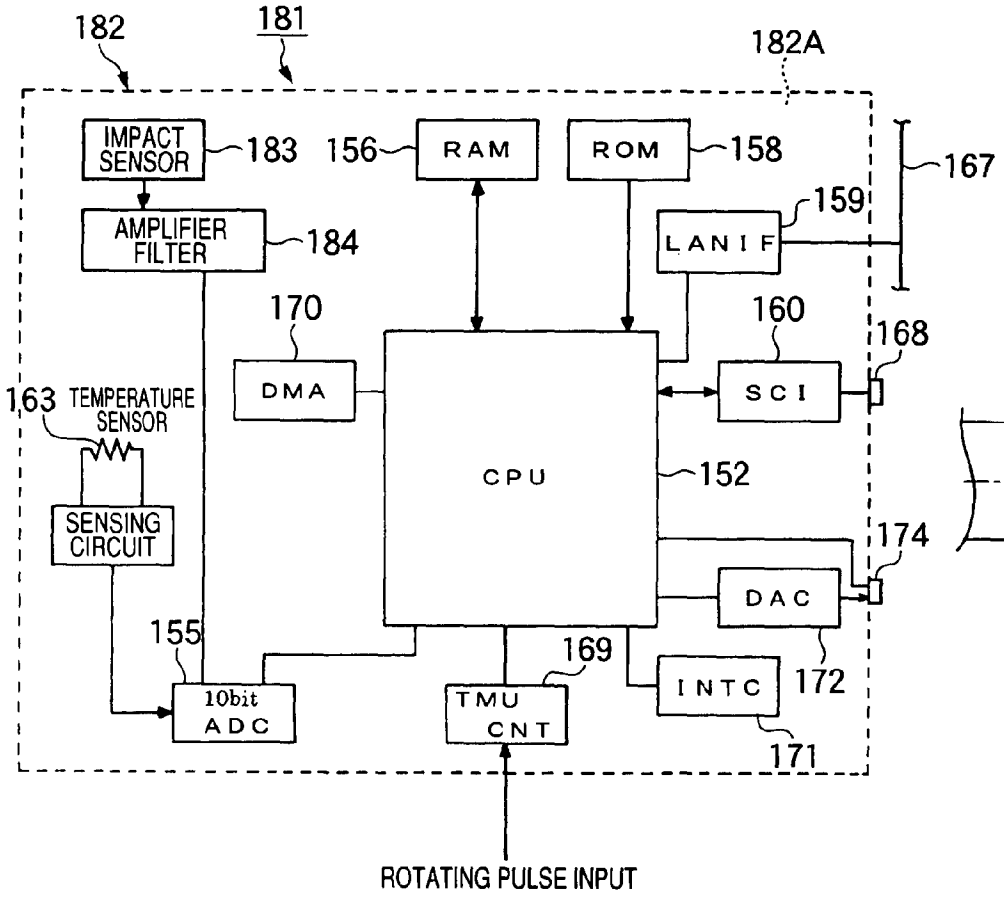


FIG. 35(b)

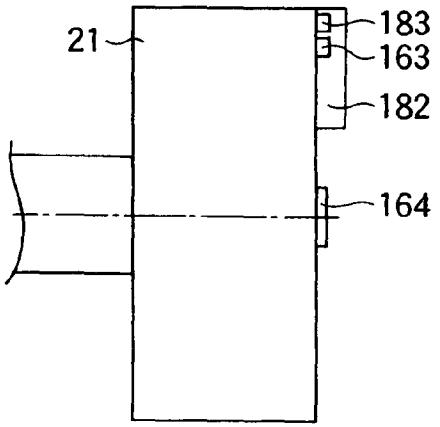


FIG. 36

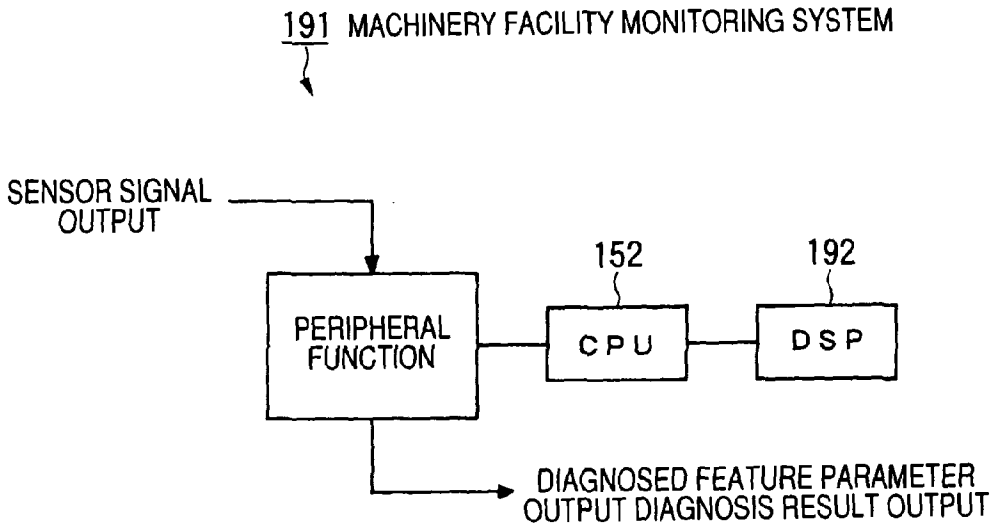

191 MACHINERY FACILITY MONITORING SYSTEM
SENSOR SIGNAL OUTPUT
PERIPHERAL FUNCTION
152
CPU
192
DSP
DIAGNOSED FEATURE PARAMETER OUTPUT DIAGNOSIS RESULT OUTPUT

FIG. 37

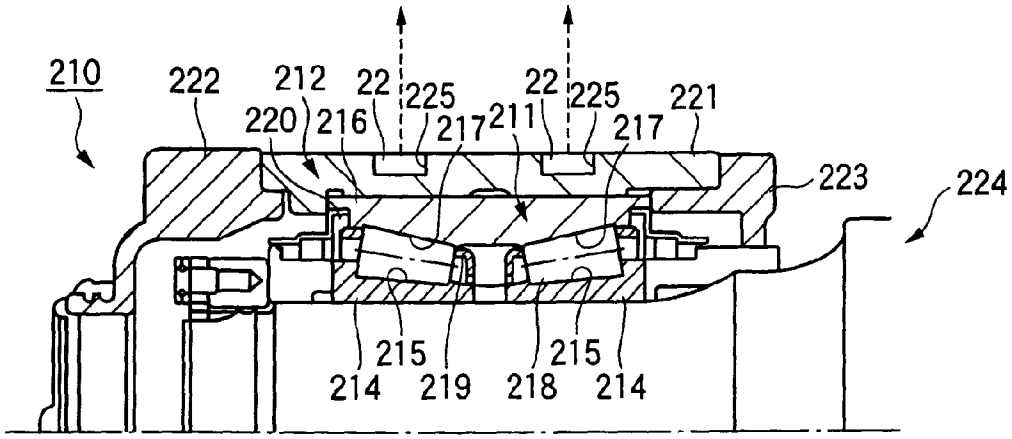

210
222
212
220
216
22
225
217
211
22
225
217
221
223
224
215
214
219
218
215
214

FIG. 38

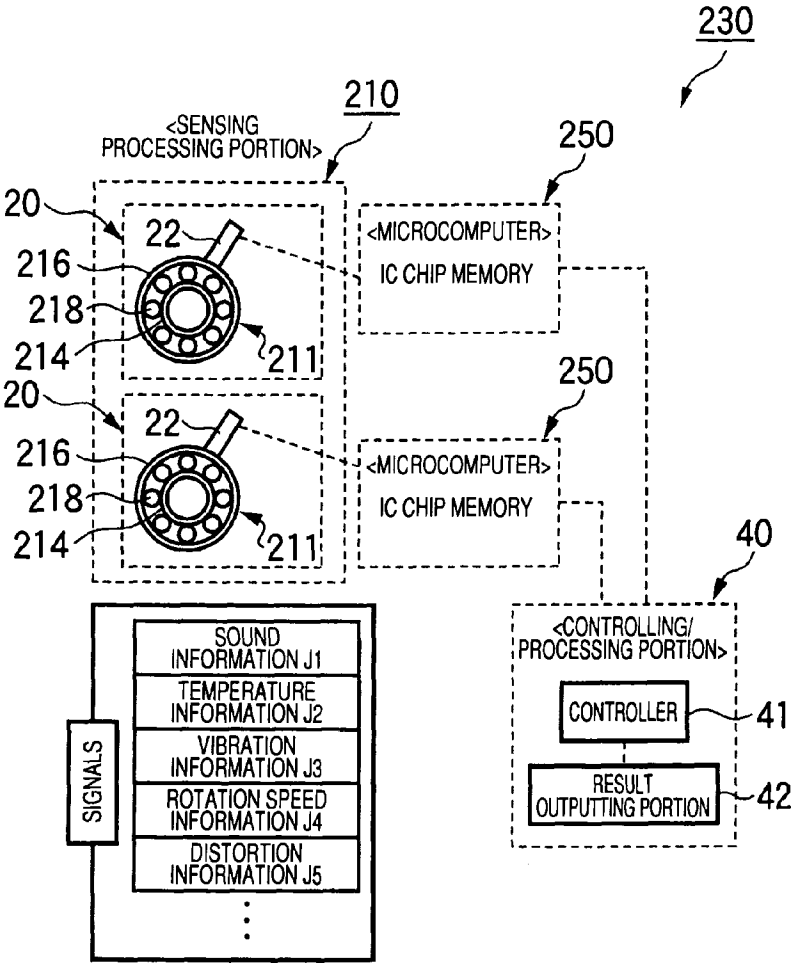

230
210
<SENSING PROCESSING PORTION>
250
20
22
216
218
214
211
<MICROCOMPUTER>
IC CHIP MEMORY
250
20
22
216
218
214
211
<MICROCOMPUTER>
IC CHIP MEMORY
40
<CONTROLLING/ PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUTTING PORTION
42
SIGNALS
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5

FIG. 39

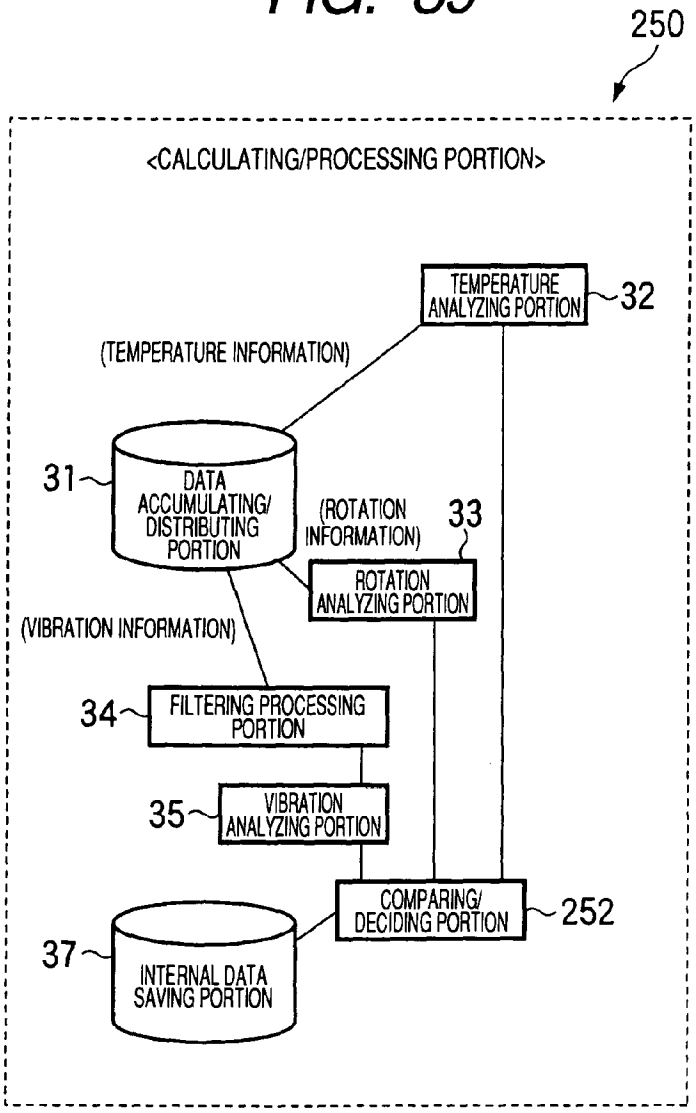

250
<CALCULATING/PROCESSING PORTION>
TEMPERATURE ANALYZING PORTION
32
(TEMPERATURE INFORMATION)
31
DATA ACCUMULATING/ DISTRIBUTING PORTION
(ROTATION INFORMATION)
33
ROTATION ANALYZING PORTION
(VIBRATION INFORMATION)
34
FILTERING PROCESSING PORTION
35
VIBRATION ANALYZING PORTION
COMPARING/ DECIDING PORTION
252
37
INTERNAL DATA SAVING PORTION

FIG. 40

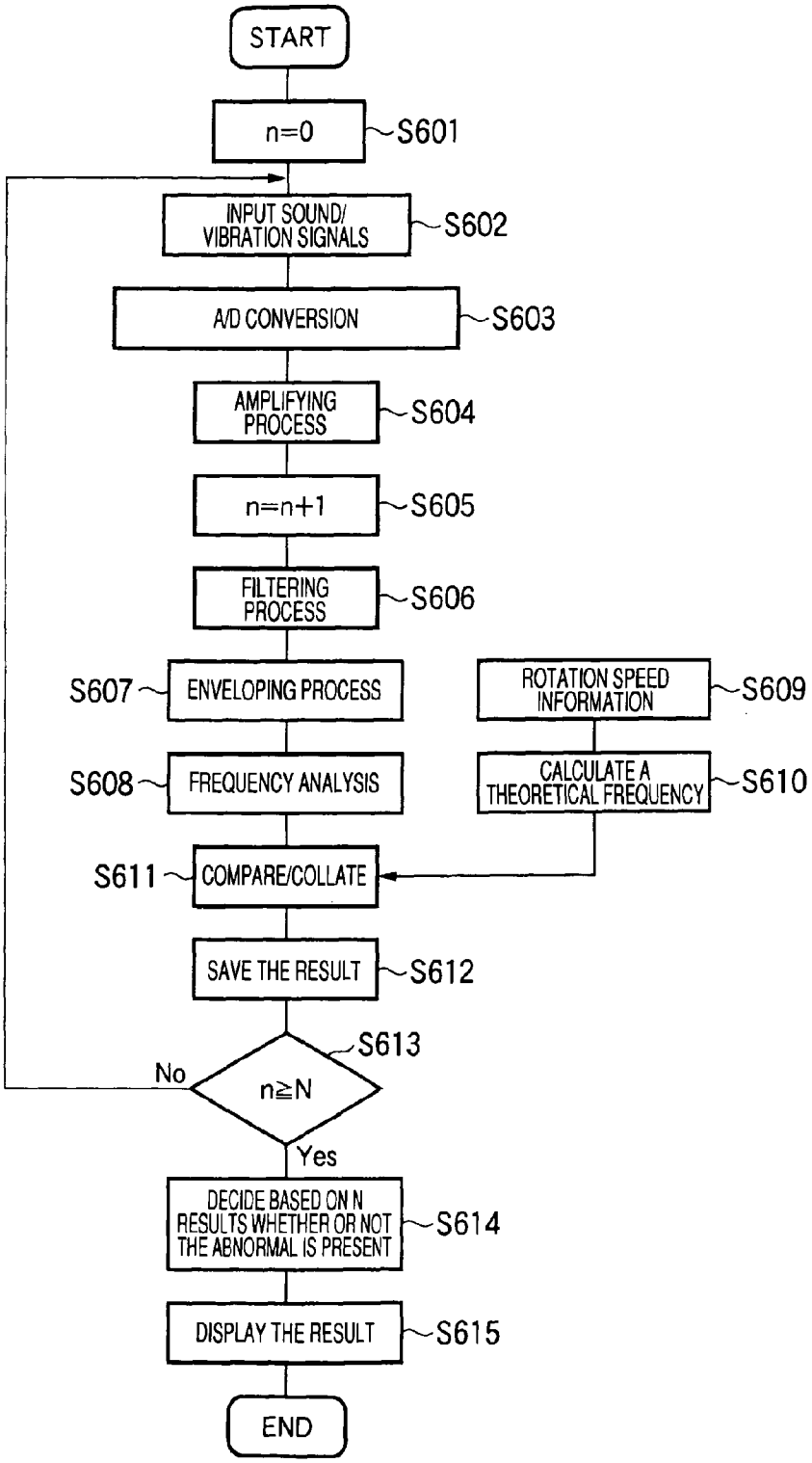

START
n=0
S601
INPUT SOUND/ VIBRATION SIGNALS
S602
A/D CONVERSION
S603
AMPLIFYING PROCESS
S604
n=n+1
S605
FILTERING PROCESS
S606
S607
ENVELOPING PROCESS
ROTATION SPEED INFORMATION
S609
S608
FREQUENCY ANALYSIS
CALCULATE A THEORETICAL FREQUENCY
S610
S611
COMPARE/COLLATE
SAVE THE RESULT
S612
S613
No
n≧N
Yes
DECIDE BASED ON N RESULTS WHETHER OR NOT THE ABNORMAL IS PRESENT
S614
DISPLAY THE RESULT
S615
END

FIG. 41

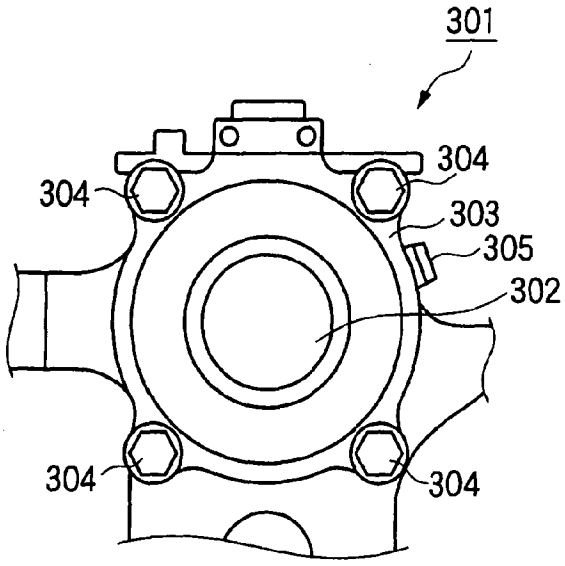
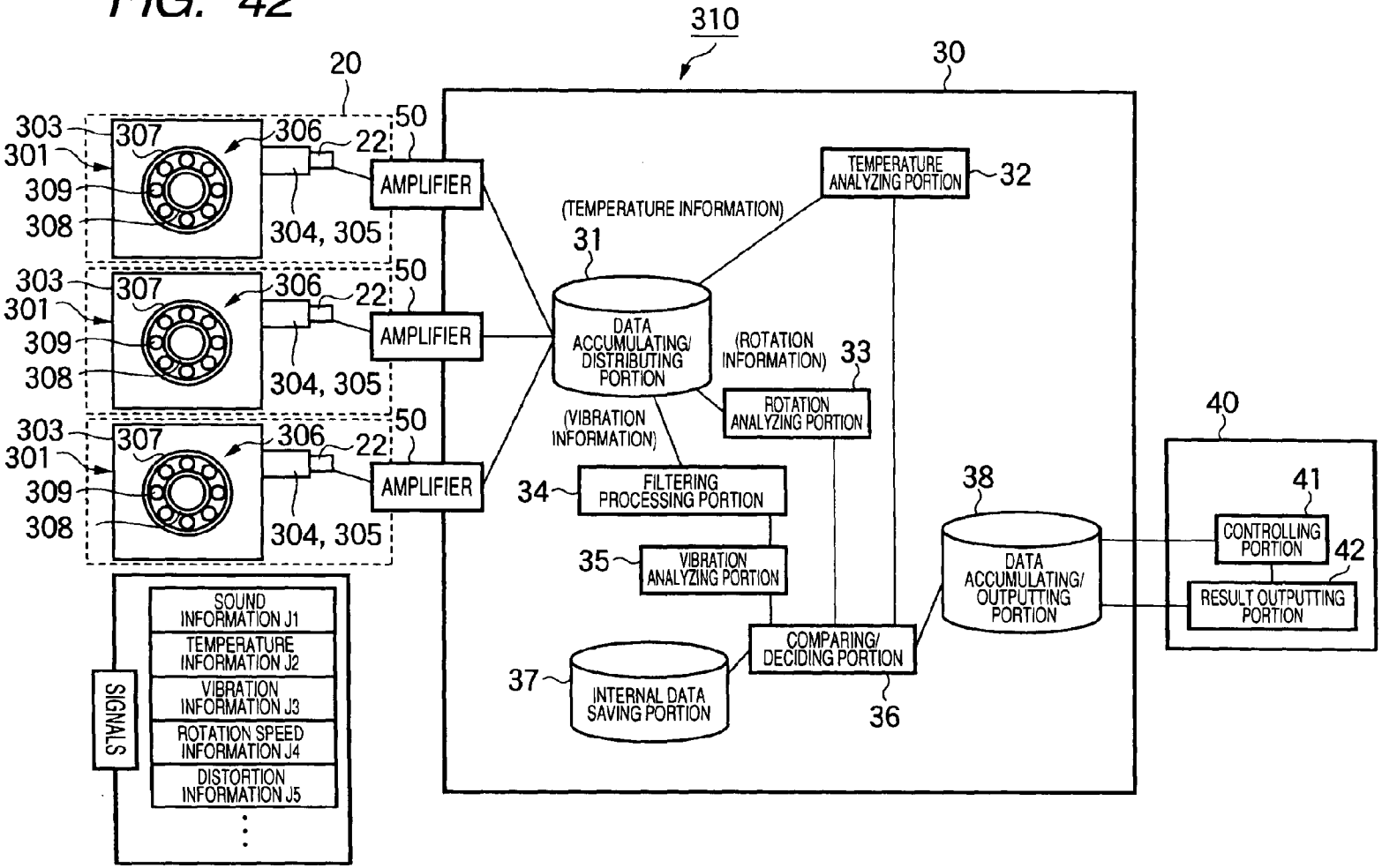


FIG. 42



EP 1 548 419 A1

FIG. 43

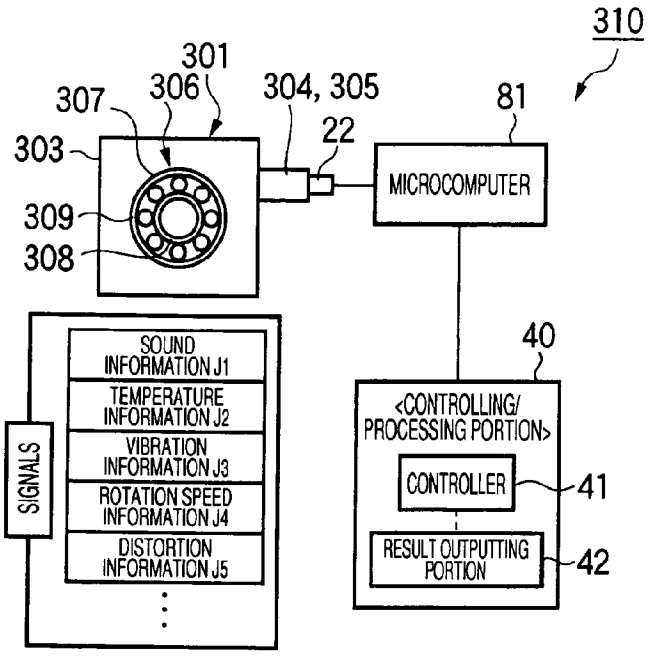

310
301
307
306
304, 305
81
303
22
MICROCOMPUTER
309
308
SOUND INFORMATION J1
TEMPERATURE INFORMATION J2
VIBRATION INFORMATION J3
ROTATION SPEED INFORMATION J4
DISTORTION INFORMATION J5
SIGNALS
40
<CONTROLLING/ PROCESSING PORTION>
CONTROLLER
41
RESULT OUTPUTTING PORTION
42

FIG. 44

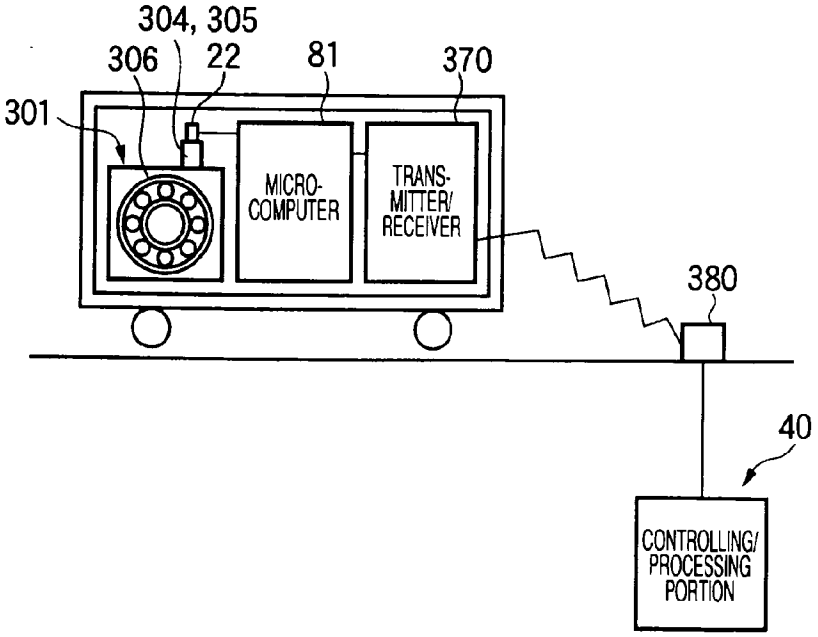

304, 305
306
22
81
370
301
MICRO-COMPUTER
TRANS-MITTER/ RECEIVER
380
40
CONTROLLING/ PROCESSING PORTION

FIG. 45

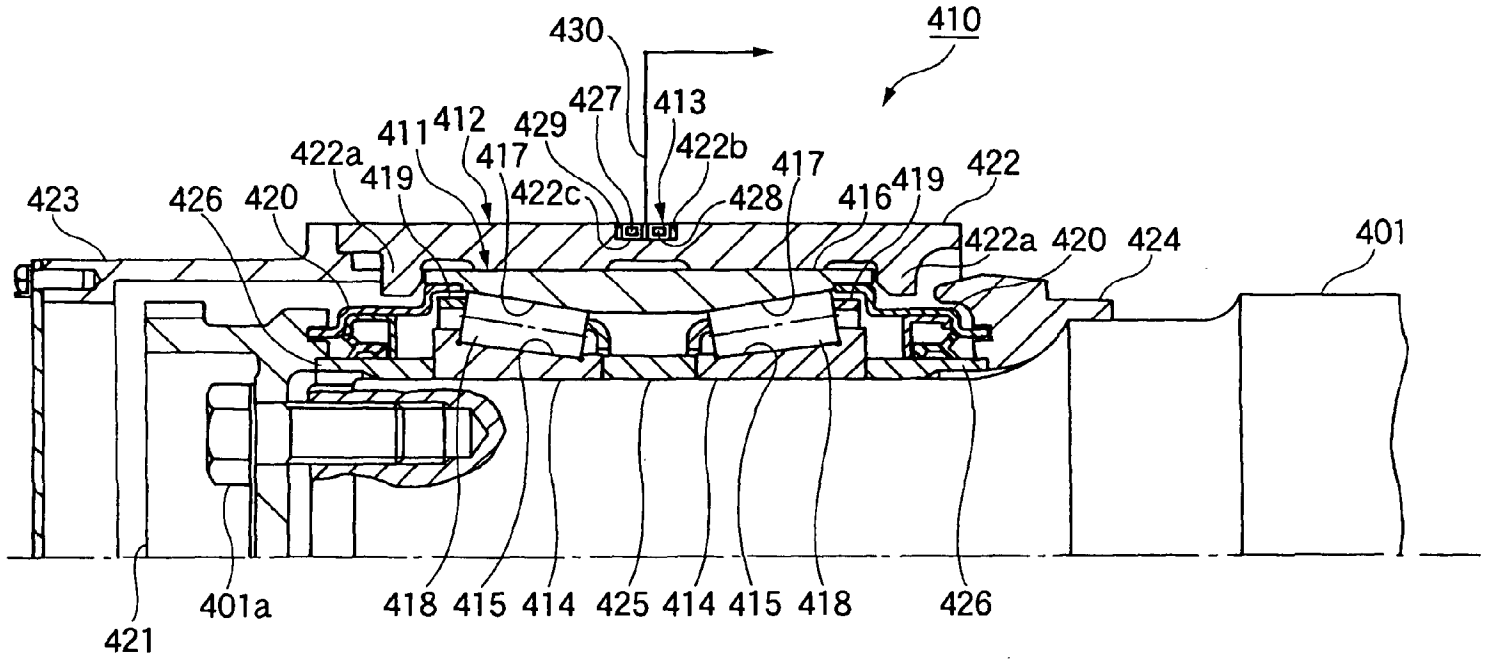

430
410
427
413
411
412
429
422a
417
422b
417
422
419
422c
428
416
419
423
426
420
422a
420
424
401
401a
418
415
414
425
414
415
418
426
421

FIG. 46

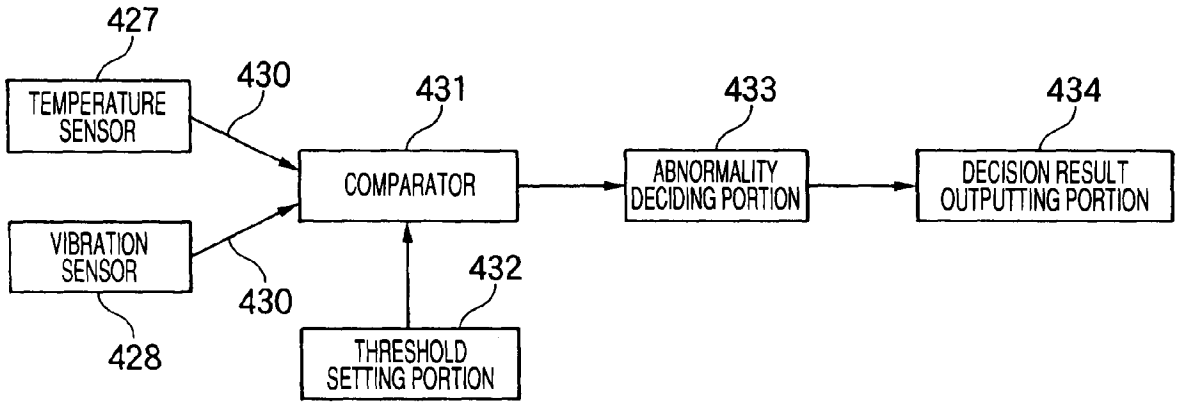

427
TEMPERATURE SENSOR
430
431
433
434
COMPARATOR
ABNORMALITY DECIDING PORTION
DECISION RESULT OUTPUTTING PORTION
VIBRATION SENSOR
430
432
428
THRESHOLD SETTING PORTION

FIG. 47

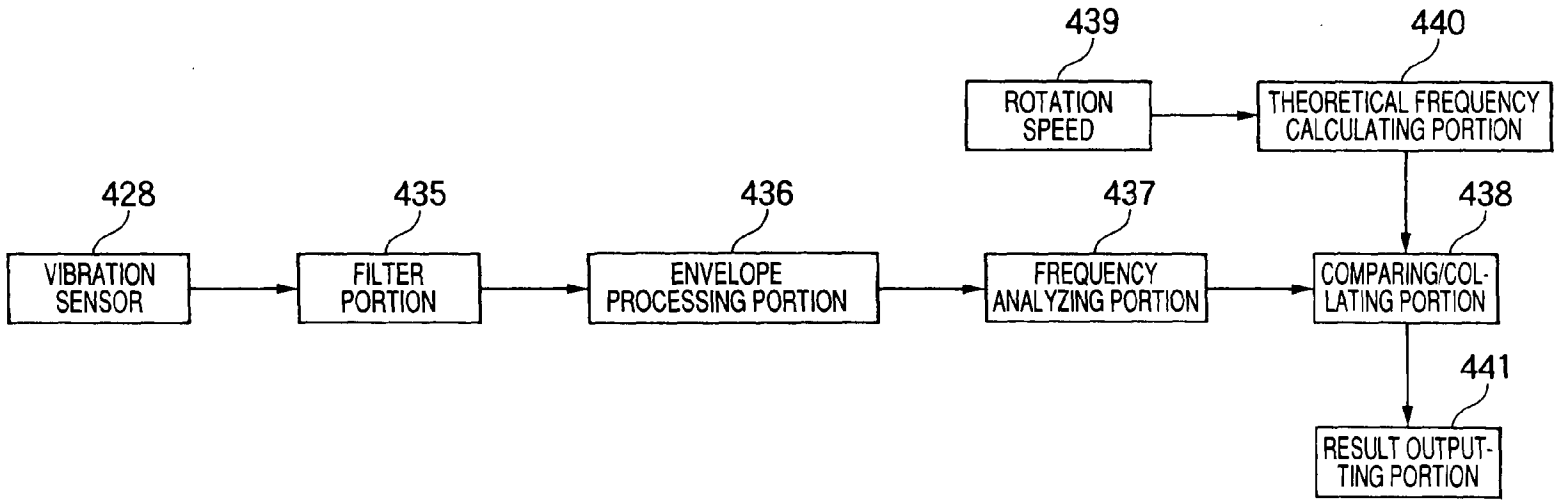

439
440
ROTATION SPEED
THEORETICAL FREQUENCY CALCULATING PORTION
428
435
436
437
438
VIBRATION SENSOR
FILTER PORTION
ENVELOPE PROCESSING PORTION
FREQUENCY ANALYZING PORTION
COMPARING/COL-LATING PORTION
441
RESULT OUTPUT-TING PORTION

FIG. 48

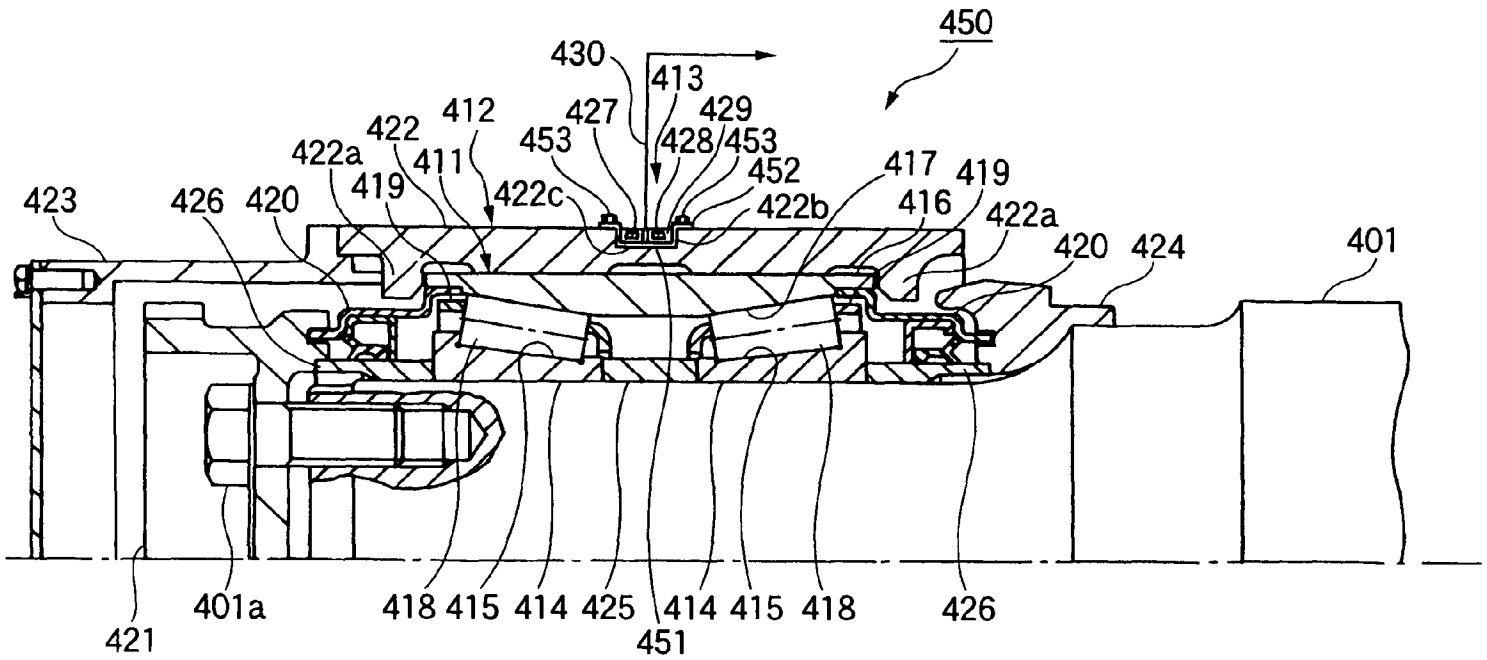

450
430
413
427
429
412
422
453
428
453
422a
411
452
417
419
423
426
420
419
422c
422b
416
422a
420
424
401
421
401a
418
415
414
425
451
414
415
418
426

FIG. 49

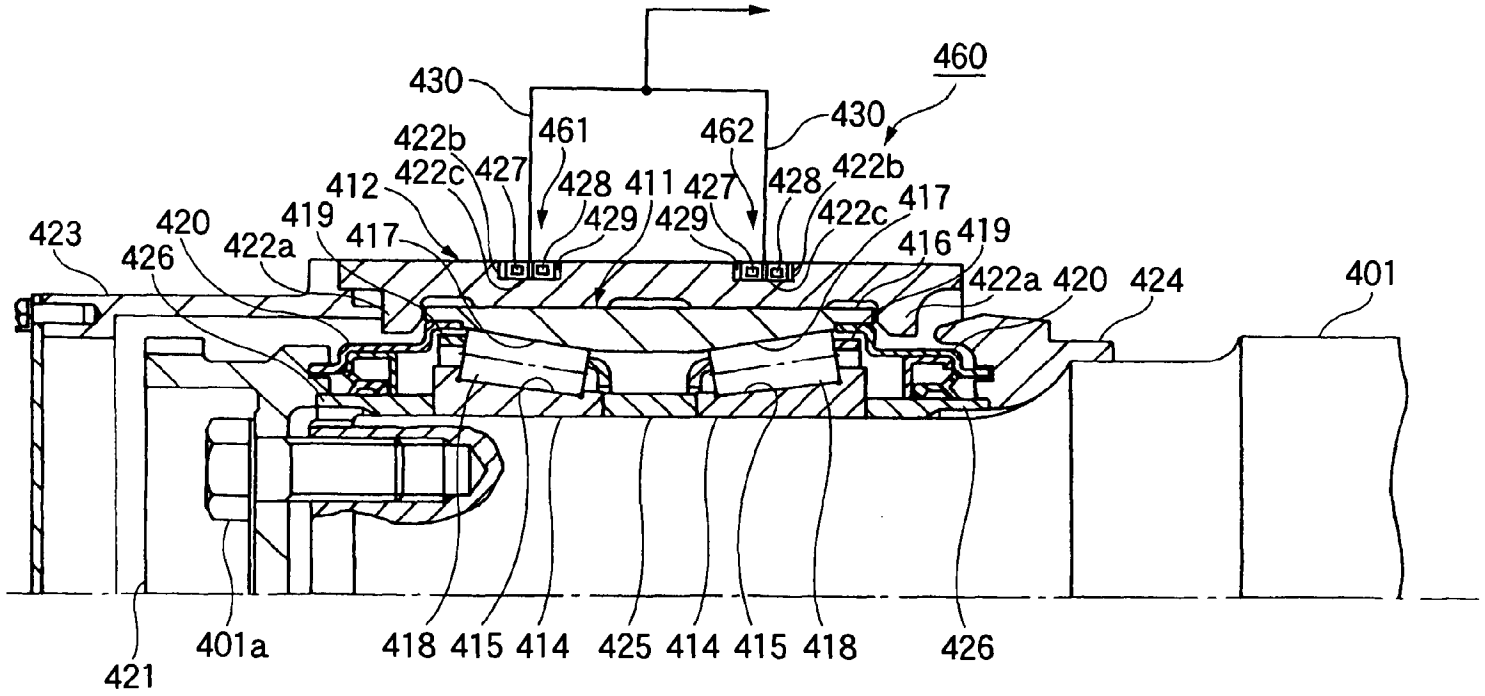

460
430
461
462
430
422b
422c
427
428
411
427
428
422b
412
429
429
422c
417
419
417
416
419
423
420
426
422a
422a
420
424
401
401a
418
415
414
425
414
415
418
426
421

FIG. 50

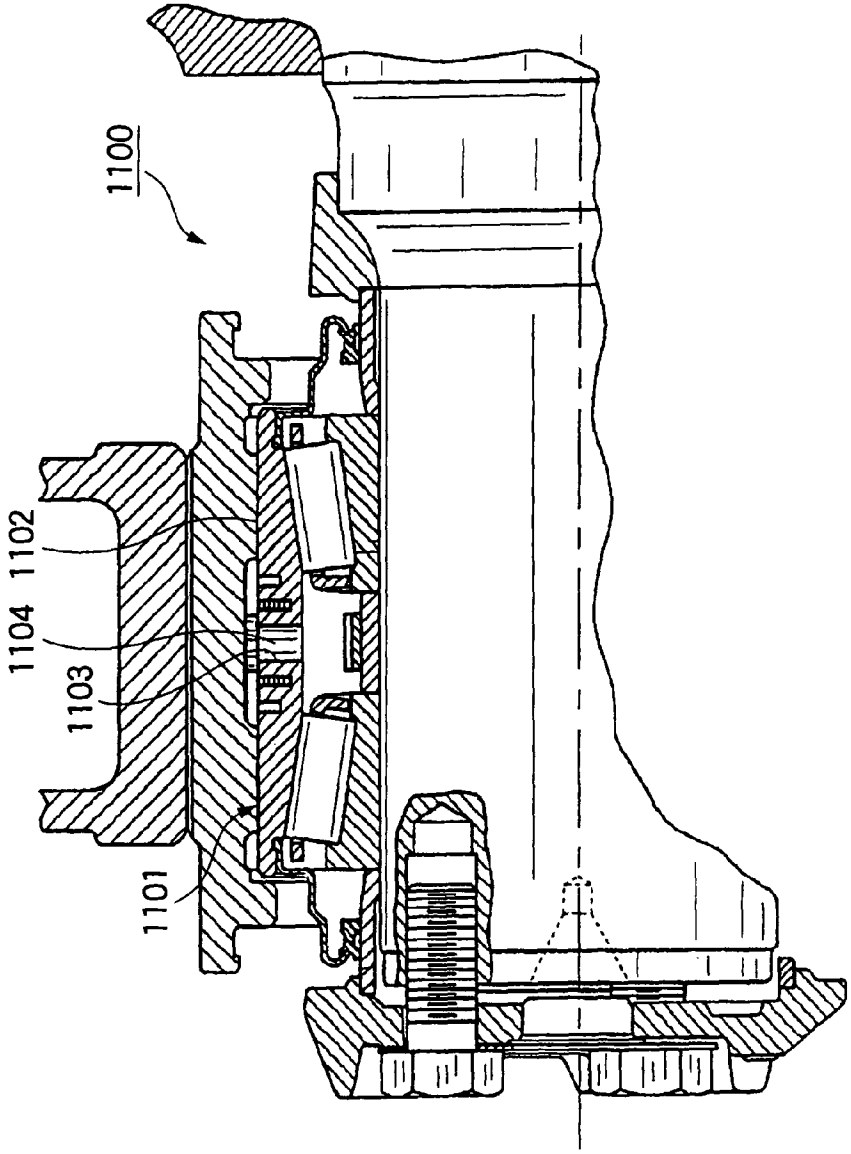


FIG. 51

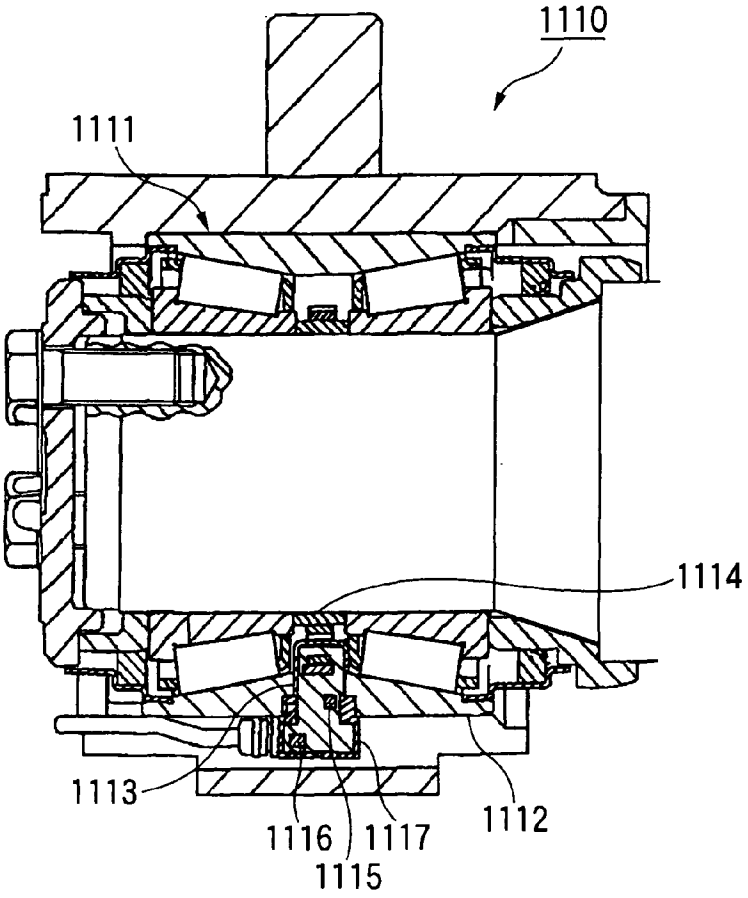


FIG. 52

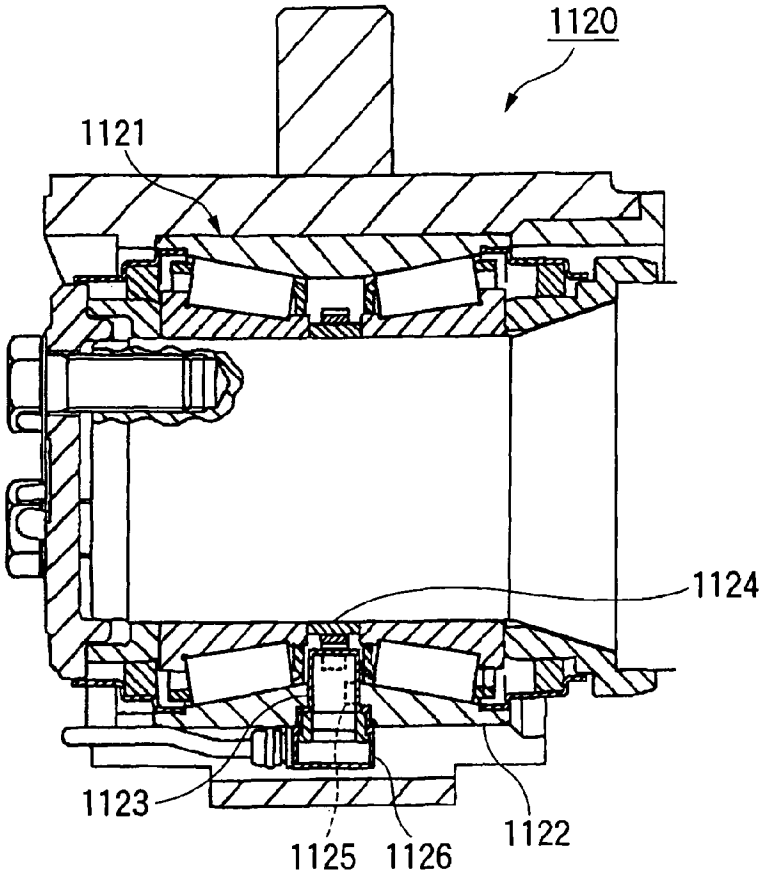


FIG. 53

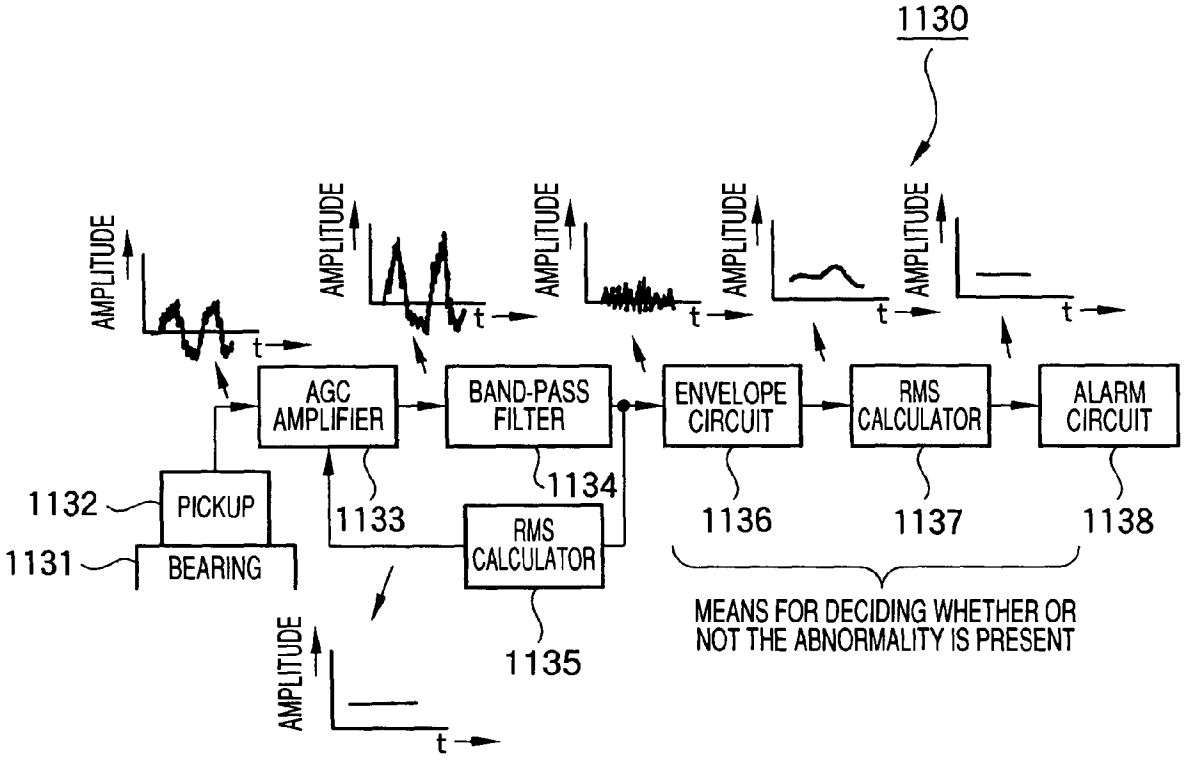

1130
AMPLITUDE
t
AGC AMPLIFIER
BAND-PASS FILTER
ENVELOPE CIRCUIT
RMS CALCULATOR
ALARM CIRCUIT
1132
PICKUP
1131
BEARING
1133
1134
RMS CALCULATOR
1135
1136
1137
1138
MEANS FOR DECIDING WHETHER OR NOT THE ABNORMALITY IS PRESENT

FIG. 54

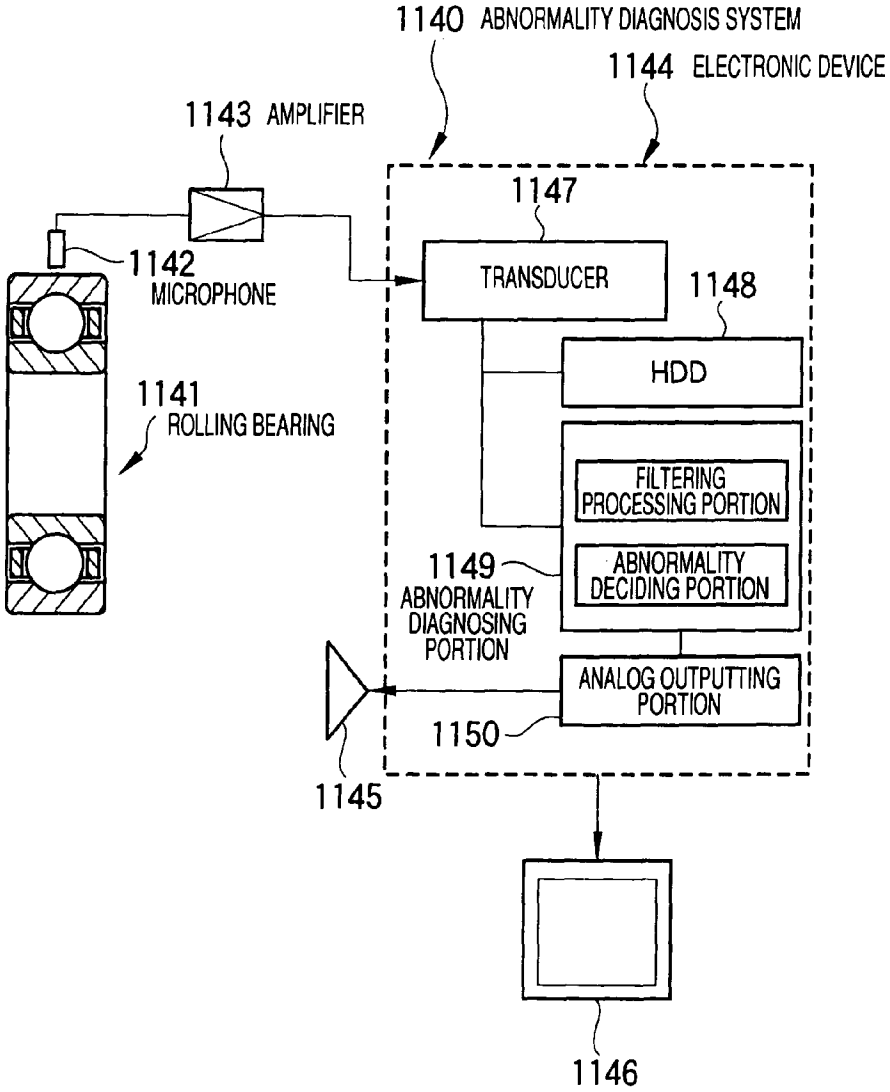
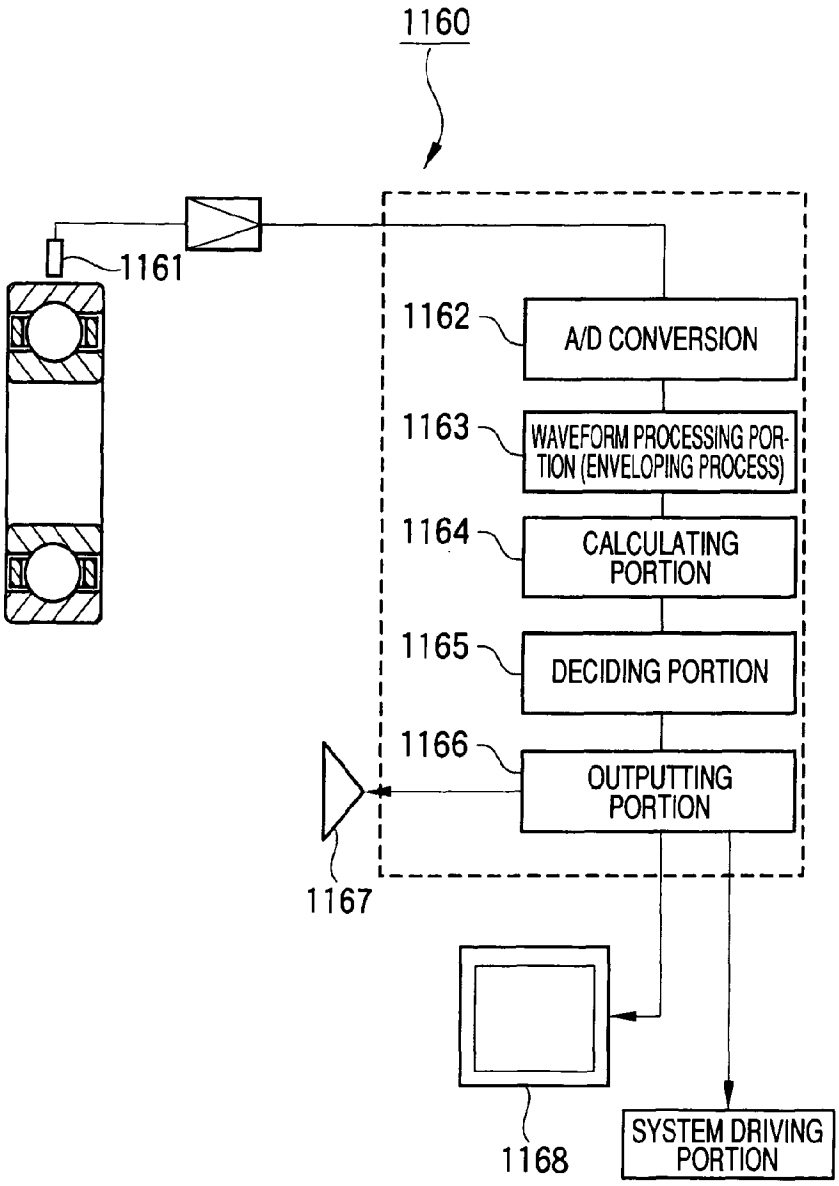

1140 ABNORMALITY DIAGNOSIS SYSTEM
1144 ELECTRONIC DEVICE
1143 AMPLIFIER
1147
1142
MICROPHONE
TRANSDUCER
1148
HDD
1141
ROLLING BEARING
FILTERING PROCESSING PORTION
1149
ABNORMALITY DIAGNOSING PORTION
ABNORMALITY DECIDING PORTION
ANALOG OUTPUTTING PORTION
1150
1145
1146

FIG. 55


1160
1161
1162
A/D CONVERSION
1163
WAVEFORM PROCESSING PORTION (ENVELOPING PROCESS)
1164
CALCULATING PORTION
1165
DECIDING PORTION
1166
OUTPUTTING PORTION
1167
1168
SYSTEM DRIVING PORTION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/11114

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] G01M13/04, G01M19/00, G01M17/08, F16C41/00, B61F15/20, G01D21/00, G01B21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] G01M13/04, G01M19/00, G01M17/08, F16C41/00, B61F15/20, G01D21/00, G01B21/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2003
Kokai Jitsuyo Shinan Koho 1971-2003 Jitsuyo Shinan Toroku Koho 1996-2003

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2002-71519 A (NTN Corp.), 08 March, 2002 (08.03.02), Par. Nos. [0001], [0014], [0023] to [0070] & EP 1164550 A2 & US 2002-13635 A1	38-43 1-37,44-60
Y	JP 2001-21453 A (NSK Ltd.), 26 January, 2001 (26.01.01), Par. Nos. [0008], [0012] to [0046]; all drawings (Family: none)	1-24,46-48, 60
Y	JP 7-209143 A (Caterpillar Inc.), 11 August, 1995 (11.08.95), Par. Nos. [0002] to [0114]; all drawings & US 5566092 A1	1-23,37,49

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December, 2003 (10.12.03)	24 December, 2003 (24.12.03)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/11114

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6-200929 A (AB SKF), 19 July, 1994 (19.07.94), Par. Nos. [0006], [0014], [0015], [0024]; Figs. 1 to 2 & EP 594550 A1	4-5, 29,31, 36
Y	WO 98/11356 A1 (THE TIMKEN CO.), 19 March, 1998 (19.03.98), Full text; all drawings & JP 2001-500597 A & US 6161962 A1	6,17,22, 26-35,44,49, 51-59
Y	JP 47-9446 A (General Electric Co.), 15 May, 1972 (15.05.72), Full text; all drawings (Family: none)	7,9,23
Y	JP 3-152436 A (Koyo Seiko Co., Ltd.), 28 June, 1991 (28.06.91), Full text; all drawings (Family: none)	8,45,53, 55-57
Y	JP 2-240536 A (Fuji Electric Co., Ltd.), 25 September, 1990 (25.09.90), Full text; all drawings (Family: none)	10-14
Y	JP 6-42983 A (Omron Corp.), 18 February, 1994 (18.02.94), Par. Nos. [0019] to [0024]; all drawings & EP 581218 A1 & US 5407730 A1	25,36
Y	JP 2000-133474 A (Asahi National Shomei Kabushiki Kaisha), 12 May, 2000 (12.05.00), Full text; all drawings (Family: none)	32

Form PCT/ISA/210 (continuation of second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/11114

Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1-37 relate to an abnormality diagnosing device for rolling stock mechanical equipment.
Claims 38-48 relate to a method and a device for monitoring the status of mechanical equipment.
Claims 49-52 relate to an abnormality diagnosing device for a mechanical device.
Claims 53-60 relate to a bearing having an abnormality detecting means.

A scope within which the International Preliminary Examination Organization considers to fulfill the requirement of unity of invention involves the respective four groups of the above claims.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1998)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 650 191 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.10.2013 Bulletin 2013/42

(51) Int Cl.:
B61K 9/04 *(2006.01)*

(21) Application number: **12163973.6**

(22) Date of filing: **12.04.2012**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **Progress Rail Services Corporation**
Albertville, AL 35950 (US)

(72) Inventor: **Agostini, Alessandro**
50134 Firenze (IT)

(74) Representative: **Modiano, Micaela Nadia**
Modiano & Partners (IT)
Via Meravigli, 16
20123 Milano (IT)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) Method of detecting and signalling a hot box condition

(57) A method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices (10); relaying temperature data through a wireless network of the hot box detection devices (10) to a data recorder.

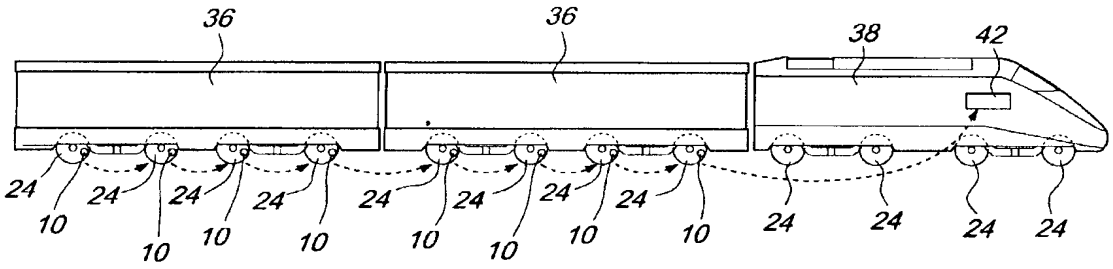


Fig. 2

EP 2 650 191 A1

Printed by Jouve, 75001 PARIS (FR)

BNSDOCID: <EP_____2650191A1_I_>

Description

Technical Field

[0001] This disclosure generally relates to the field of rail transportation and to determining a temperature of rail vehicle undercarriage components. In particular, this disclosure relates to detecting temperatures of rail vehicle undercarriage and relaying information relating to the detected temperatures.

Background

[0002] Safe and reliable operation of a railroad system may be dependent upon the integrity of the rolling mechanisms of the vehicles travelling over the rails, such as trains. Worn or damaged train wheel bearings may increase the rolling friction of the axle thereby increasing the power required to pull the train. In addition, worn or damaged bearings may cause excessive wear to the train axle and, in the case of failure of the bearing, may even cause the axle to lock up, preventing rotation of the wheel and thus resulting in a potential fire hazard due to the heat build up and potential sparking caused by friction of the locked wheel scraping along the rail.

[0003] Bearing temperatures may be scanned by sensing a temperature of the wheel bearing indirectly through a bearing box surrounding the wheel bearing on a rail car of a train. When the bearing temperatures are high due to overheating of the wheel bearing a hot box condition may exists. For example, infrared radiation (IR) sensors may be mounted along a rail to detect IR energy emitted by an outer wheel bearing of passing rail cars. The IR energy may be indicative of a temperature of the wheel bearing.

[0004] Wheel temperatures may be scanned by sensing a temperature of the wheel directly. When the bearing temperatures are high due to overheating of the wheel a hot wheel condition may exist. For example, infrared radiation (IR) sensors may be mounted along a rail to detect IR energy emitted by an outer wheel bearing of passing rail cars. The IR energy may be indicative of a temperature of the wheel bearing.

[0005] However, such a system may be limited to bearing or wheel temperatures being scanned only at specific points on the railway paths. For rail car transporting potentially dangerous or dangerous cargo there may be a need for the bearing or wheel temperatures to be scanned continuously so that any changes in temperature may be detected within a short time.

[0006] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of the prior art system.

Brief Summary of the Invention

[0007] In a first aspect, the present disclosure describes a method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices; relaying temperature data through a wireless network of the hot box detection devices to a data recorder.

[0008] In a second aspect, the present disclosure describes a system for performing the method of detecting and signalling a hot box condition on a rail vehicle, the system comprising temperature sensors provided in hot box detection devices to acquire temperature data from undercarriage components of the rail vehicle; and a wireless network of the hot box detection devices for relaying the temperature data to a data recorder.

Brief Description of the Drawings

[0009] The foregoing and other features and advantages of the present disclosure will be more fully understood from the following description of various embodiments, when read together with the accompanying drawings, in which:

Fig. 1 is a schematic representation of a device for detecting a hot box condition on a rail vehicle undercarriage component according to the present disclosure; and

Fig. 2 is a schematic representation of a system for detecting a hot box condition on a rail vehicle undercarriage component according to the present disclosure.

Detailed Description

[0010] This disclosure generally relates to a device **10** for detecting a hot box/ hot wheel condition on a rail vehicle undercarriage component.

[0011] With reference to Fig. 1, the hot box detection device **10** may comprise a housing **12**. The housing **12** may have a container-like structure. The housing **12** may have a structure to accommodate the temperature sensor and any required electronics. The housing **12** may be configured so as to be positioned on an undercarriage component of a rail vehicle. The housing **12** may have a suitable shape and structure to be positioned on the undercarriage component. The housing **12** may be composed of thermal insulation materials.

[0012] The device **10** may be coupled to the undercarriage component. The housing **12** may be coupled to directly on the undercarriage component. The housing **12** may be suitably coupled to the undercarriage component. In an embodiment, the housing **12** may be removably coupled to the undercarriage component. The housing **12** may be magnetically coupled to the undercarriage component. The housing **12** may be in magnetic contact with the undercarriage component. The magnetic coupling may be sufficiently strong to hold the device **10** as a sole means of direct fastening.

BNSDOCID: <EP_____2650191A1_I_>

[0013] The housing **12** may be provided with a magnet for magnetic coupling to the undercarriage component. The magnet may be disposed within the housing **12.** In an embodiment, the housing **12** may be provided with a plurality of magnets for magnetic coupling to the undercarriage component. The plurality of magnets may be disposed within the housing **12** and suitably arranged therein. The magnet or the plurality of magnets may be permanent magnets.

[0014] In an embodiment, a portion of the housing **12** may be magnetised for magnetic coupling to the undercarriage component. The portion of the housing **12** in contact with undercarriage component may be magnetised. The portion of the housing **12** may be constituted by a permanent magnet. The portion of the housing **12** may incorporate a permanent magnet. The permanent magnet may be incorporated into a wall of the housing **12.**

[0015] In an embodiment, the housing **12** may be magnetised for magnetic coupling to the undercarriage component. The housing **12** may be constituted by a permanent magnet. The housing **12** may incorporate a permanent magnet. The permanent magnet may be incorporated into a wall of the housing **12.**

[0016] The device **10** may further comprise a temperature sensor. The temperature sensor may be positioned within the housing **12.** The temperature sensor may detect heat from the target undercarriage component. The temperature sensor may acquire data from the target undercarriage component by detecting the temperature thereof. The temperature sensor may detect a hot box condition or a hot wheel condition through the evaluation of the IR signals emitted from the target undercarriage component.

[0017] In an embodiment, the temperature sensor may be an IR sensor for determining the temperature of the target undercarriage component. The infrared sensor may analyze the infrared emissions from the target undercarriage component to determine the temperature thereof. The infrared sensor may be pulsed and/or operated in intervals to consume only low power. Signals from the infrared sensor may be used to determine if hot box condition or a hot wheel condition persists.

[0018] The device **10** may comprise other detectors. The device **10** may comprise an acceleration detector to detect additional forces acting on a wheel subjected to scanning by the acceleration detector.

[0019] The temperature sensor may be positioned within the housing **12.** The temperature sensor may be positioned within the housing **12** in a position that allows heat from the target undercarriage component to be detected. The temperature sensor may be positioned within the housing **12** in a position that allows the temperature of the target undercarriage component to be measured.

[0020] The rail undercarriage **20** may comprise components such as an axle **22,** wheels **24,** wheel bearings **26** and axle stubs **28.** The device may be located so as to obtain IR data from the one of the target rail vehicle undercarriage components.

[0021] The device **10** may be located on the undercarriage component. The device **10** may be located on the target undercarriage component the temperature of which is to be measured by the temperature sensor. The device may be positioned on the axle **22,** wheels **24,** wheel bearings **26** or axle stubs **28.**

[0022] In an embodiment, the device **10** may be located on one undercarriage component adjacent to the target undercarriage component. The device **10** may be positioned on a wheel **24** and orientated to measure the temperatures of the wheel bearing **26** or the axle **22.** The device may be positioned on the axle **22** and orientated to measure the temperature of the wheel **24.** The device **10** may be positioned on an axle stub **28** and orientated to measure the temperatures of the wheel bearing **26** or the wheel **24.**

[0023] The rail vehicle may travel on the rails **32** of a rail track **30** that may be positioned on a rail bed, such as within a cross tie or a sleeper **34.**

[0024] The device **10** may be provided with electronics which includes a controller to control the temperature sensor. The controller may analyse the signals from the temperature sensor. The electronics may be configured to communicate wirelessly. The electronics may be configured to operate within a wireless network.

[0025] The device **10** may be powered by a battery. The temperature sensor may be powered by the battery. The electronics and associated controller may be powered by the battery. In an embodiment, the battery may be a lithium battery which is able to provide a power supply over a period of 1 to 2 years.

[0026] In an embodiment, the device **10** may be powered through rotational acceleration. The temperature sensor may be powered through rotational acceleration. The electronics and associated controller may be powered through rotational acceleration. The rotation force on the temperature sensor may generate electrical power for the operation of the temperature sensor.

[0027] The housing **12** is supported on the undercarriage component, and the housing **12** may support a generator configured to produce electrical power when the undercarriage component, such as a rail vehicle wheel or axle, turns as the rail vehicle moves. Circuitry may be supported in the housing **12** and may receive the electrical power.

[0028] Electrical power may be generated through electromagnetic induction. In an embodiment, the power supply may be an electromagnetic generator. The power source may comprise a magnetic core. In an embodiment, the magnetic core may have a plurality of stationary permanent magnets that are arranged in succession in the circumferential direction, with their poles alternating. The power supply may further comprise a winding encircling the magnetic core. The magnetic core may produce a magnetic flux which passes through the winding and also passes through an air gap. A ring having teeth may be positioned such that the teeth may pass through the air gap when the ring rotates. The air gap may be between

BNSDOCID: <EP_____2650191A1_I_>

the magnetic core and teeth provided on the ring.

[0029] When the ring rotates, the teeth move through the air gap between the alternating polarity poles, causing change in flux linkage with the winding and inducing voltage across the winding. The power supply may contain a full wave rectifier and a voltage regulator which converts the alternating current generated in the winding to direct current.

[0030] In an embodiment, the ring may be rotatably mounted in the housing **12.** The ring may be weighted such that as the undercarriage component rotates the weight would tend to remain in its lowest position in the housing **12.** The position which would be equivalent to the weight rotating within the housing **12** in the opposite direction as the rotation of the undercarriage component.

[0031] As the undercarriage component rotates, the magnetic core may rotate relative to the ring and the teeth. The relative rotation may move the teeth though the air gap so as to induce a voltage. The voltage may be used to supply power to the device **10** and the components therein.

[0032] With reference to Fig. 2, this disclosure also relates to a system **40** for performing a method of detecting and signalling a hot box condition on a rail vehicle **36.** The system **40** may comprise the devices **10** for detecting a hot box condition on a rail vehicle undercarriage component.

[0033] The system **40** may comprise temperature sensors for acquiring temperature data from undercarriage components of the rail vehicle **36.** The temperature sensors may be disposed in the devices **10.** The system may comprise a wireless network of the devices **10** for relaying the temperature data to a data recorder **42.**

[0034] In an embodiment, the data recorder **42** may be located in a rail vehicle **36.** In an embodiment, the data recorder **42** may be located in a locomotive **38** to which a plurality of rail vehicles **36** are linked.

[0035] The devices **10** may be removably coupled to the undercarriage components. The devices **10** may be coupled magnetically to the undercarriage components. The undercarriage components may be rotating components. The devices **10** may be positioned on the axle **22,** wheels **24,** wheel bearings **26** or axle stubs **28.**

[0036] The devices **10** may be powered through rotational acceleration force. The devices **10** may be powered through a battery.

[0037] The devices **10** may be magnetically coupled to undercarriage components.

[0038] In operation, the devices **10** may be switched on sequentially starting from locomotive **38** end towards the end of the train. For instance, each device **10** may self configure within a wireless network of the devices **10** at activation.

[0039] In an embodiment, the devices **10** may be configured to transmit data to the nearest device **10.** In an embodiment, the devices **10** may be configured to transmit data to the nearest active device **10** from the locomotive **38** side of the train. In Fig. 2 the arrows may indicate the relay of data from a device **10** to the next nearest active device **10** from the locomotive **38** side of the train. The data may be relayed to the data recorder **42.**

[0040] In an embodiment, each device **10** may be configured so as to transmit data to all the other devices **10.** Each device **10** may be configured so as to transmit data to all other devices **10** which are nearer to the locomotive **38.** The broadcast of the data may ensure that multipath and redundant transmissions up to the first device **10** proximate to the locomotive **38.**

[0041] The device **10** next to the locomotive **38** may transmit a signal to the data recorder **42.** The data recorder **42** may have a display to provide information to the train driver. The data recorder **42** may have an alarm display to inform the train driver of any dangerous condition.

[0042] A method of detecting and signalling a hot box condition on a rail vehicle may comprise the step of acquiring temperature data from undercarriage components of the rail vehicle. The temperature data may be acquired through temperature sensors provided in the devices **10.** The method may further comprise relaying the temperature data through a wireless network of the devices **10** to a data recorder.

[0043] The method may comprise the steps of sequencing the devices **10** and relaying the temperature data detected by each of devices **10** to the next device **10** in the sequence.

[0044] The method may comprise the step of broadcasting the temperature data detected by each of the devices **10** to the remaining devices **10** in the network.

[0045] The method may comprise the step of transmitting the temperature data to wayside stations. The wayside stations may be positioned along the train track **30.** The wayside stations may be positioned at intervals along the train track **30.** The temperature data may be transmitted to wayside stations by the data recorder **42.**

[0046] The method may comprise the step of powering the devices **10** through rotational acceleration force.

[0047] The method may comprise the step of coupling the device **10** to each undercarriage component wherein the housing **12** is coupled magnetically.

[0048] The skilled person would appreciate that foregoing embodiments may be modified or combined to obtain the device **10** or the system **40** of the present disclosure.

Industrial Applicability

[0049] This disclosure describes a device **10** which can be positioned with ease on the rail vehicle undercarriage component. The device **10** may be temporarily coupled to the rail vehicle undercarriage component. Such a temporary coupling may avoid the need for the device **10** to be manufactured as a part of the rail vehicle undercarriage component. Thus, the device **10** may be assembled without the need for retrofitting the under carriage component. The device **10** may be decoupled from the un-

BNSDOCID: <EP_____2650191A1_I_>

dercarriage component after use without undue effort. The device **10** may be used as a consumable item.

[0050] The device **10** may be in direct contact with the rail vehicle undercarriage component and thereby may be able to measure the temperature of the component directly.

[0051] This disclosure describes a system **40** comprising a network of devices **10** which are linked wirelessly for the transmission of data. The data acquired by a device **10** may be transmitted from said device to the next device **10** in line from the data recorder **42.** The data may be relayed through the series of devices **10** to the data recorder **42.**

[0052] The data may be relayed through a series of devices **10** in sequence. The data may be broadcast from one device **10** to other devices **10** in the network. The network of devices **10** may ensure multipath and redundant transmissions.

[0053] Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above- described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein.

[0054] Where technical features mentioned in any claim are followed by references signs, the reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, neither the reference signs nor their absence have any limiting effect on the technical features as described above or on the scope of any claim elements.

[0055] One skilled in the art will realise the disclosure may be embodied in other specific forms without departing from the disclosure or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the disclosure described herein. Scope of the invention is thus indicated by the appended claims, rather than the foregoing description, and all changes that come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

Claims

1. A method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of:

   acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices (10);
   relaying temperature data through a wireless network of the hot box detection devices (10) to a data recorder.

2. The method of claim 1 comprising the steps of sequencing the hot box detection devices and relaying the temperature data detected by each of the hot box detection devices (10) to the next hot box detection device (10) in the sequence.

3. The method of claim 1 or 2 comprising the step of broadcasting the temperature data detected by each of the hot box detection devices (10) to the remaining hot box detection devices (10) in the network.

4. The method of any one of the preceding claims comprising the step of transmitting the temperature data to wayside stations.

5. The method of claim 4 wherein the temperature data is transmitted to wayside stations by the data recorder.

6. The method of any one of the preceding claims comprising the step of powering the hot box detection devices (10) through rotational acceleration force.

7. The method of any one of the preceding claims comprising the step of coupling the hot box detection device (10) to each undercarriage component wherein the housing (12) is coupled magnetically.

8. A system (40) for performing the method of detecting and signalling a hot box condition on a rail vehicle, the system (40) comprising:

   temperature sensors provided in hot box detection devices (10) to acquire temperature data from undercarriage components of the rail vehicle; and
   a wireless network of the hot box detection devices (10) for relaying the temperature data to a data recorder.

9. The system of claim 8 wherein hot box detection devices (10) are removably coupled to the undercarriage components, wherein each hot box detection devices (10) being coupled magnetically.

10. The system according to claim 9 wherein the undercarriage components are rotating component.

11. The system according to claim 10 wherein the undercarriage component is a wheel.

12. The system according to claim 10 wherein the undercarriage component is an axle.

13. The system according to any one of the preceding claims 9 to 12 wherein hot box detection devices (10) are powered through rotational acceleration force.

14. The system according to any one of the preceding

BNSDOCID: <EP_____2650191A1_I_>

claims 9 to 12 wherein the hot box detection devices (10) are powered through a battery.

Amended claims in accordance with Rule 137(2) EPC.

1. A method of detecting and signalling a hot box condition on a rail vehicle comprising the steps of:

acquiring temperature data from undercarriage components of the rail vehicle through temperature sensors provided in hot box detection devices (10); and
relaying temperature data through a wireless network of the hot box detection devices (10) to a data recorder,

characterised in the step of removably coupling the hot box detection device (10) to each undercarriage component wherein the hot box detection device (10) is coupled magnetically.

2. The method of claim 1 comprising the steps of sequencing the hot box detection devices and relaying the temperature data detected by each of the hot box detection devices (10) to the next hot box detection device (10) in the sequence.

3. The method of claim 1 or 2 comprising the step of broadcasting the temperature data detected by each of the hot box detection devices (10) to the remaining hot box detection devices (10) in the network.

4. The method of any one of the preceding claims comprising the step of transmitting the temperature data to wayside stations.

5. The method of claim 4 wherein the temperature data is transmitted to wayside stations by the data recorder.

6. The method of any one of the preceding claims comprising the step of powering the hot box detection devices (10) through rotational acceleration force.

7. A system (40) for performing the method of detecting and signalling a hot box condition on a rail vehicle, the system (40) comprising:

temperature sensors provided in hot box detection devices (10) to acquire temperature data from undercarriage components of the rail vehicle; and
a wireless network of the hot box detection devices (10) for relaying the temperature data to a data recorder,

characterised in that the hot box detection devices (10) are removably coupled to the undercarriage components, wherein the hot box detection devices (10) are coupled magnetically.

8. The system according to claim 7 wherein the undercarriage components are rotating components.

9. The system according to claim 8 wherein the undercarriage component is a wheel.

10. The system according to claim 8 wherein the undercarriage component is an axle.

11. The system according to any one of the preceding claims 7 to 10 wherein hot box detection devices (10) are powered through rotational acceleration force.

12. The system according to any one of the preceding claims 7 to 10 wherein the hot box detection devices (10) are powered through a battery.

BNSDOCID: <EP_____2650191A1_I_>

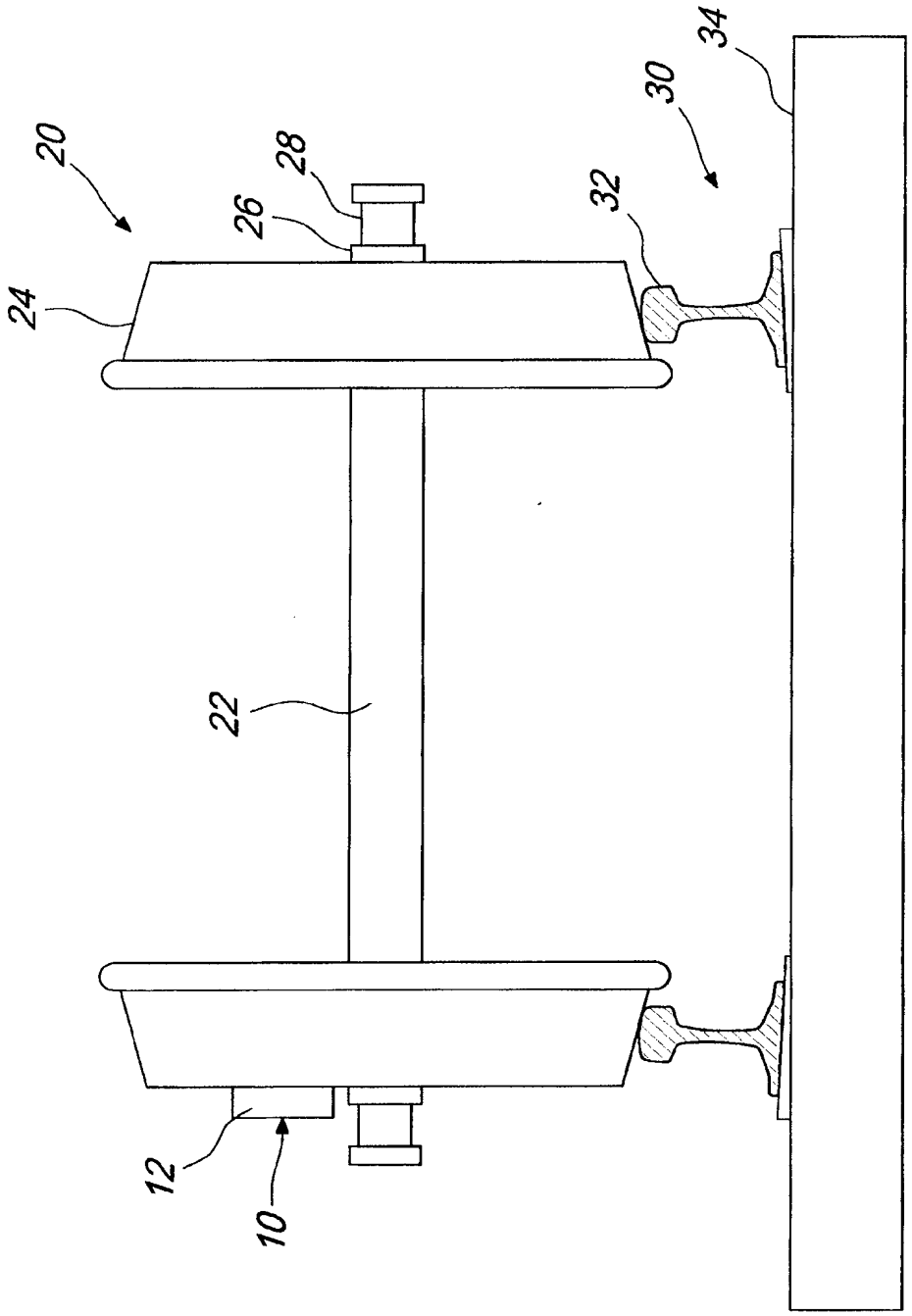


Fig. 1

BNSDOCID: <EP_____2650191A1_I_>

BNSDOCID: <EP_____2650191A1_I_>

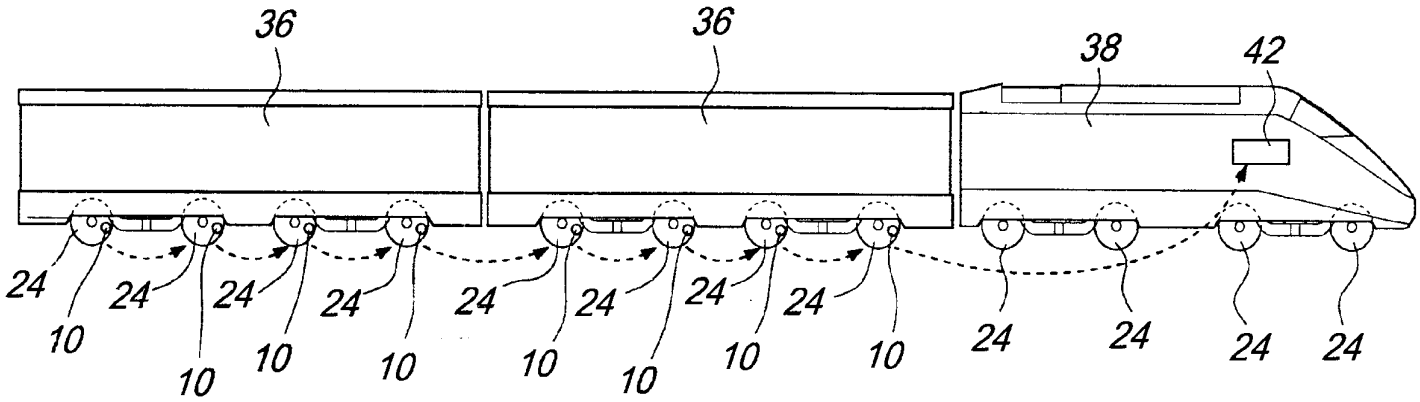


Fig. 2

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 05-213195

(43)Date of publication of application : 24.08.1993

(51)Int.Cl. B61F 5/24
B60G 17/00
B60G 17/015
G05D 19/02
// F16F 9/50

(21)Application number : 03-089644

(22)Date of filing : 27.03.1991

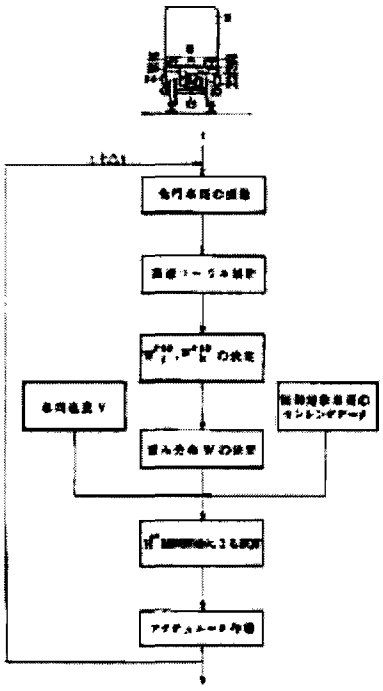
(71)Applicant : SUMITOMO METAL IND LTD

(72)Inventor : ISHIHARA KOICHIRO
KOIZUMI TOMOSHI
TORII OSAMU
HIRATA TOSHIAKI

(54) METHOD FOR RESTRAINING VIBRATION OF RAILWAY VEHICLE BY ACTIVE CONTROL

(57)Abstract:

PURPOSE: To improve a control effect and comfortebleness by frequency analyz ing the vibration of e leading vehicle or vehicle in front of an objective vehicle of a composed train by carrying out H control such that the maximum value of the H control weight is in a half value width of the frequency and the distri bution of the weight in the half value width is a predetermined one.



CONSTITUTION: The frequency analysis of vibration of a vehicle is carried out by the outputs of respective vibration accelometers 21, 22, a relative displacement meter 23 and vertical displacement meter 24 of a leading vehicle of a composed train. That is, high speed Fourier conversion is carried out by a controller to determine a half value width (WPSD1, WPSDh) of power spectrum density and weight distribution W. The weight distribution W is determined to be between the maximum value and -10dB. H control

theory calculation is carried out on the basis of vehicle speed V end sensing data of the vehicle to be controlled to operate an actuator 25.

(19)日本国特許庁（ＪＰ）　(12)**公開特許公報**（Ａ）　(11)特許出願公開番号

特開平5－213195

(43)公開日　平成５年(1993)８月24日

(51)Int.Cl.[5]	識別記号	庁内整理番号	ＦＩ	技術表示箇所
Ｂ６１Ｆ　5/24	Ｃ	9255－3D		
	Ａ	9255－3D		
	Ｂ	9255－3D		
	Ｆ	9255－3D		
Ｂ６０Ｇ　17/00		8817－3D		

審査請求　未請求　請求項の数１(全　７　頁)　最終頁に続く

(21)出願番号　特願平3－89644

(22)出願日　平成３年(1991)３月27日

(71)出願人　000002118
住友金属工業株式会社
大阪府大阪市中央区北浜４丁目５番33号

(72)発明者　石原　広一郎
大阪府大阪市中央区北浜４丁目５番33号
住友金属工業株式会社内

(72)発明者　小泉　智志
大阪府大阪市中央区北浜４丁目５番33号
住友金属工業株式会社内

(72)発明者　鳥居　修
大阪府大阪市中央区北浜４丁目５番33号
住友金属工業株式会社内

(74)代理人　弁理士　押田　良久

最終頁に続く

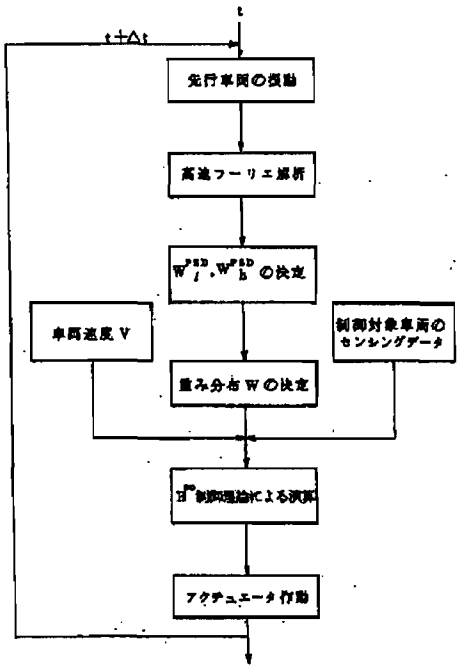
(54)【発明の名称】　鉄道車両のアクティブ制御による振動抑制方法

(57)【要約】

【目的】　鉄道車両の振動のアクティブ制御を行なうに当り制御効果をより高める。

【構成】　一編成列車の先頭車両か、対象車両に対する先行車両の振動を周波数解析し、その周波数の半値幅内にH∞制御の重みが最大値を有し、かつその半値幅内の重みは最大値から－１０ｄＢ以内になる分析となるように決定したH∞制御を施す。

【効果】　効果的な振動抑制を行なうことにより制御効果をより高めることができる。



1

【特許請求の範囲】

【請求項1】　車両の振動を抑制し乗り心地の向上を図るためのアクティブ制御付き台車の制御方法において、一編成列車の先頭車両か、あるいは対象車両の前方に位置する車両の振動を周波数解析し、その周波数の半値幅内にH■制御の重みが最大値を有し、かつその半値幅内の重みは最大値から－10dB以内になる分布となるように決定したH■制御を施すことを特徴とする鉄道車両のアクティブ制御による振動抑制方法。

【発明の詳細な説明】

【0001】

【産業上の利用分野】この発明は、鉄道車両の列車編成とH■制御理論に特有な振動抑制周波数の効率的な選択の長所を生かして行なう鉄道車両のアクティブ制御による振動抑制方法に関する。

【0002】

【従来の技術】鉄道車両の車体に発生する左右振動には、図11に示すように車体11の中心に揺動中心O_rがあるヨーイング、図12に示す車体11の下方に揺動中心O_lがある下心ローリング、および図13に示す車体11の上方に揺動中心O_uがある上心ローリングの3種類がある。前記左右振動を抑制する方法としては、車体と台車の間に振動方向に合せてアクチュエータを設置し、該車体の振動に対し逆位相の制御力を発生させるのが一般的である。

【0003】従来の鉄道車両のアクティブサスペンション装置としては、特開昭56－17754号公報の「車両の振動制御装置」および特開昭59－156860号公報の「車両の振動制御装置」等が知られている。その構成は、図14に示すように、車体11（車体前部11_f、車体後部11_rで示す）を支持するばね12_f、12_rの間に設置された複動形空気圧シリンダ13_f、13_rを空気圧サーボ弁15_f、15_rで駆動する方式となっており、該空気圧サーボ弁への制御入力は、前記車体11に設置された加速度検知計16_f、16_rの出力を用いて、積分、一次進み、一次遅れおよびゲイン要素から構成される数1あるいは数2の形のアナログ補修回路17_f、17_rにて決定される。

【0004】

【数1】

$$\frac{K(1+T_1S)}{s(1+T_2S)}$$

【0005】

【数2】

$$\frac{K(1+T_1S)(1+T_3S)}{s(1+T_2S)(1+T_4S)}$$

【0006】前記3種類の左右振動は、それぞれ異なった固有振動数を持つため、前記アナログ補修回路17_f、17_rをそれぞれの左右振動の固有振動数で最適なゲイン、位相を持つように設計すれば、常に左右振動を抑制することができる。なお、図中の18は空気源を示す。

2

【0007】

【発明が解決しようとする課題】鉄道車両はレールの不整により上下動、左右動、ローリングおよびヨーイングの振動加速度を受けている。これを二次ばねである空気ばねで高周波成分を遮断したり、左右動ダンパ、ヨーイングダンパで運動エネルギーを熱エネルギーに変えて車体になるべく伝達しないように工夫している。しかし、パッシブな系では、固定された共振周波数を無くすることはできない。また積極的に振動を抑制することは不可能である。

【0008】したがって、鉄道車両の振動抑制においては、アクティブ制御を取り入れることが乗り心地の飛躍的な向上に不可欠である。しかし、アクティブ制御はアクチュエータを高周波の外乱に対してもリアルタイムで高速に作動させる必要があり、センサーによる外乱のサンプリングから制御器内の演算をとおしてアクチュエータを作動させるまでの時間が短いほど良好な制御が得られ、これが重要となる。

【0009】最近、強力な制御理論として注目をあびている現代制御理論やH■制御理論は状態変数の多次元のマトリックス演算を行なう必要があり、いかに低次元の重み分布を求めて、効率的な演算で制御効果をあげるかが問題である。また、逆に車両編成という鉄道の性格上、フィード・フォワードが比較的実施しやすい環境にあり、これをうまく利用すれば制御の向上が望めるのも事実である。

【0010】しかし、制御理論として採用しようとしているH■制御は重みの最大値近傍の周波数域では相当抑制効果があるものの、少し周波数がずれると極端に効果が落ちる性質があり、全周波数域に渡って振動抑制効果を発揮させるのは難しい。

【0011】この発明は、かかる現状にかんがみ、鉄道車両の振動のアクティブ制御を行なうに当り、制御効果をより高め乗り心地の向上を図れる振動抑制方法を提供するものである。

【0012】

【課題を解決するための手段】H■制御は、制御系の伝達関数Gのゲイン‖G‖の周波数領域でのピーク値をある一定値γ以下に押える制御であることは既知である。すなわち、$\|G(j\omega)\|<\gamma$であり、ボード線図では図1に実線で示すようになる。

【0013】しかし、重み係数Wの分布を図2のように選択してH■制御を行なうと、図3に実線で示すように重みWの大の所で選択的にシャープに振動抑制効果が上がることがわかった。

3

【００１４】また、鉄道車両の振動は軌道不整によるところが大きいので、先行車両の振動の高速フーリエ変換により、図１に示す制御無の外乱の周波数分布を知れば（$\omega^{PSD}{}_{max}$）、それに一致するように後続車両の制御用の重み分布（$\omega^{H}{}_{max}=\omega^{PSD}{}_{max}$）を決定でき、図３に実線で示すように制御効果大（ゲインの小の所）の所のみを利用した制御ができる。

【００１５】この発明は上記知見に基いて完成されたものであり、車両の振動を抑制し乗り心地の向上を図るためのアクティブ制御付き台車の制御方法において、一編成列車の先頭車両か、あるいは対象車両の前方に位置する車両の振動を解析し、その周波数の半値幅内にH■制御の重みが最大値を有し、かつその半値幅内の重みは最大値から－１０ｄＢ以内になる分布となるように決定したH■制御を施すのである。

【００１６】

【作用】上記のごとく、H■制御は重み分布の決定が重要であり、重み大の所の周波数の振動が選択的かつ効果的に抑制される。したがって、先行車両の振動を解析し、振動のパワースペクトル密度の最大となる周波数域に重みが大きくなるように決定することにより後続車両のH■制御の効果を高めうる。

【００１７】すなわち、図４に示すように、先行車両（無制御車両の方がレールによる外乱を忠実に表現しているという点で望ましいが、特に限定はしない）車体振動加速度のパワースペクトル密度の半値幅（$\omega^{PSD}{}_{l}$～$\omega^{PSD}{}_{h}$間）内に重みの最大W_{max}が存在し、すなわち、

$\omega^{PSD}{}_{l} \leqq \omega^{H}{}_{max} \leqq \omega^{PSD}{}_{h}$　……１式

かつ、その間の重みが最大値から－１０ｄＢ以上である条件、すなわち、

$W(\omega) \geqq W_{max}-10dB$　……２式

（ただし、$\omega^{PSD}{}_{l} \leqq \omega \leqq \omega^{PSD}{}_{h}$）

により、十分な効果が期待できる。これを図示すると、Wは図５の斜線で示す範囲にあればよい。

【００１８】図４、図５に示すように、先行車両のパワースペクトル密度の最大値を０．１～２０Ｈｚ間の周波数域内に限定したのは、この範囲以外のレール不整による車体振動は本来少ないこと、また、２０Ｈｚを超える高周波数のアクティブ制御はアクチュエータの応答性、計算速度等を考慮すると現状では不可能といって差支えないからである。

【００１９】図４のデータは、ある一定の保守規定の元で維持されているレール上を走行する場合、あらかじめいくつかのパターンに分類しておくことで可能である。その各パターンに応じて代表的な重み分布を決定し、データベース化しておけば、リアルタイムで上記１式、２式の条件を満足するWをそのつど計算し決定する必要はなく、メモリーの呼びだしだけで制御することができ、演算時間を短縮することが可能である。

【００２０】

4

【実施例】この発明の実施例を図面に基いて説明する。アクティブ制御付き台車の構成を図６、図７に示す。各車両の車体３１に左右振動加速度計２１、上下振動加速度計２２を設け、また台車と車体の間に左右相対変位計２３、アクチュエータ用シリンダ２５を設けるとともに、台車の左右側に上下変位計２４を設ける。そして、車体の底には制御器２６を設ける。なお、図中の２８は制御信号用の配線、２９はアクチュエータ圧力計、３０はアクチュエータに供給される空気の流量計である。

【００２１】上記装置は、この発明を実施するのに必要な最も簡単な構成であり、さらに上下変位計２４に並列して上下アクチュエータを設け、または左右動、ヨーイング、ローリングに対する各ダンパを組合せて併用することもできる。

【００２２】上記列車の先頭車両の各振動加速度計、相対変位計、上下変位計からの出力により車両の振動を周波数解析し、図８のフローチャートに示す要領でH■制御理論による演算を制御器２６で行ない、その制御信号によりアクチュエータを作動して車両の振動を制御、抑制する。

【００２３】上記H■制御は、状態変数として左右加速度、左右相対変位、アクチュエータ内圧、流量弁開口面積、開口面積変化率を用い、重みは左右加速度、左右相対変位、信号出力に対して付加した。ただし、左右加速度の重みにのみ周波数依存の分布を与え、他の重みは一定値とした。また、左右加速度に対する重みの型式は次の数３で与えるものとした。

【００２４】

【数３】

$$W(S)=\frac{S^2+2\xi_2\omega_n S+\omega_n^2}{S^2+2\xi_1\omega_n S+\omega_n^2}$$

【００２５】例えば、$\omega_n=2.2\pi$、$\xi_1=0.3$、$\xi_2=2$のときの分布は図９に示すようになり、ω_nの値により最大値を示す周波数が決まり、その結果図１０に示すようにアクティブ制御により振動制御の効果の大きい周波数域が決まる。図１０はこの発明により一両の車両にH■制御を加えた結果であり、振動低減に大きな効果のあることがわかる。なお、この際の条件は、車両にヨーイングモードのｓｉｎ波加振（振幅±６ｍｍ）を加えたものである。

【００２５】

【発明の効果】上記のごとく、この発明は鉄道車両のアクティブ制御を行なうに際し、より高い制御効果が得られるようにしてH■制御を施すから、効果的な振動抑制により乗り心地を向上できる。

【図面の簡単な説明】

【図１】H■制御の一般的特性を示すボード線図である。

5

【図2】重み係数の周波数に対する分布を示す線図である。

【図3】図2の重み係数を用いた場合のH∞制御を示す線図である。

【図4】先行車両の振動を高速フーリエ解析した結果を示す線図である。

【図5】この発明の実施におけるH∞制御の重みWの決定方法を示す線図である。

【図6】この発明の実施にあたり用いたアクティブ制御付き台車を有する車両の構成を示す列車一部の説明図である。

【図7】図6の車両における制御装置の配置の概略を示す説明図である。

【図8】この発明の一実施例におけるフローチャートである。

【図9】この発明の実施における重みWの一例を示す線図である。

【図10】この発明の実施による車両一両のヨーイング加振時のH∞制御の結果を示す線図である。

6

【図11】車両に発生するヨーイングの説明図である。

【図12】車両に発生する下心ローリングの説明図である。

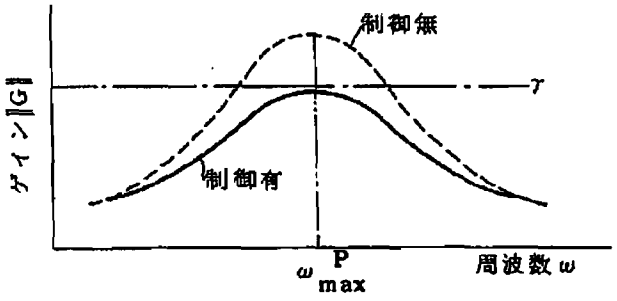
【図13】車両に発生する上心ローリングの説明図である。

【図14】従来の車両のアクティブサスペンション装置の一例を示す説明図である。

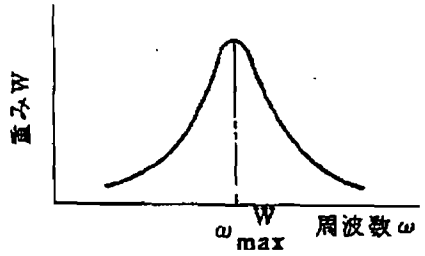
【符号の説明】

21　左右振動加速度計
22　上下振動加速度計
23　左右相対変位計
24　上下変位計
25　左右アクチュエータ用シリンダ
26　制御器
27　空気ばね
28　信号用配線
29　アクチュエータ圧力計
30　流量計
31　車体

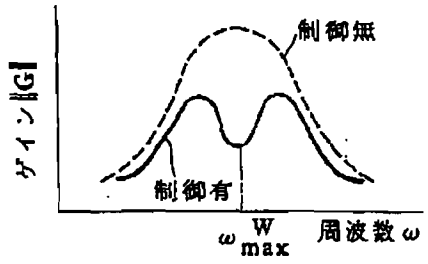
【図1】



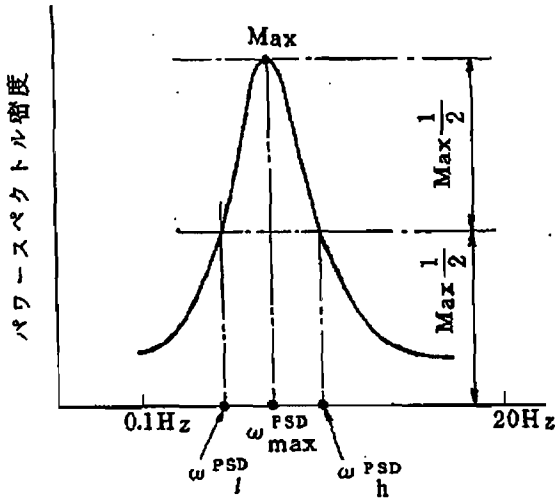
【図2】



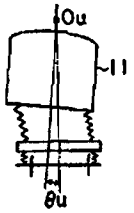
【図3】



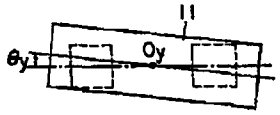
【図4】



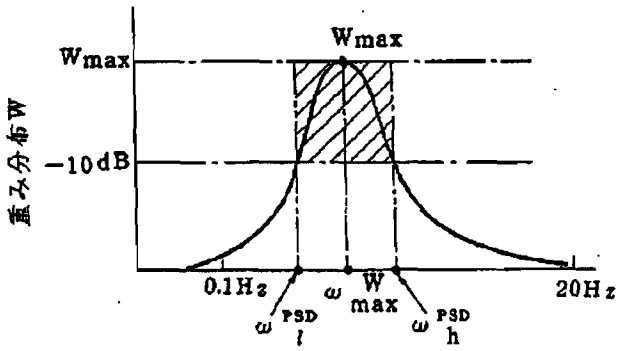
【図13】



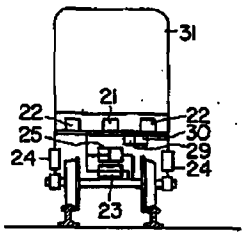
【図11】



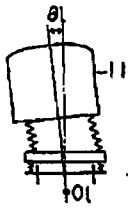
【図5】



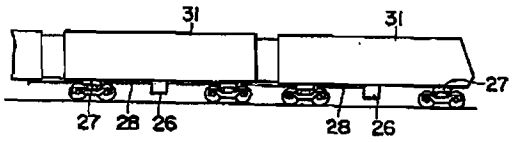
【図7】



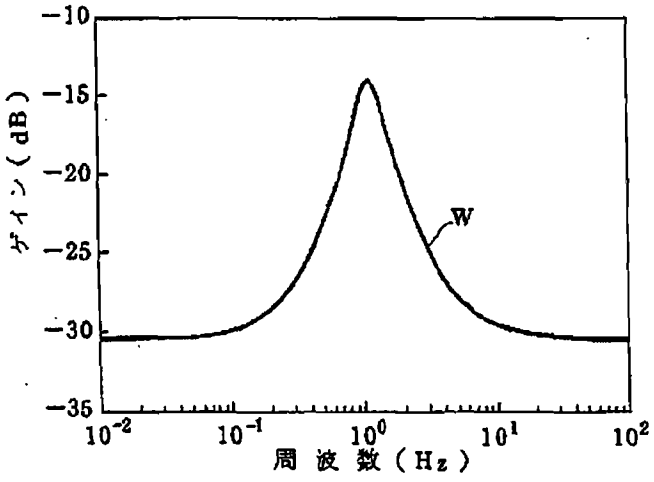
【図12】



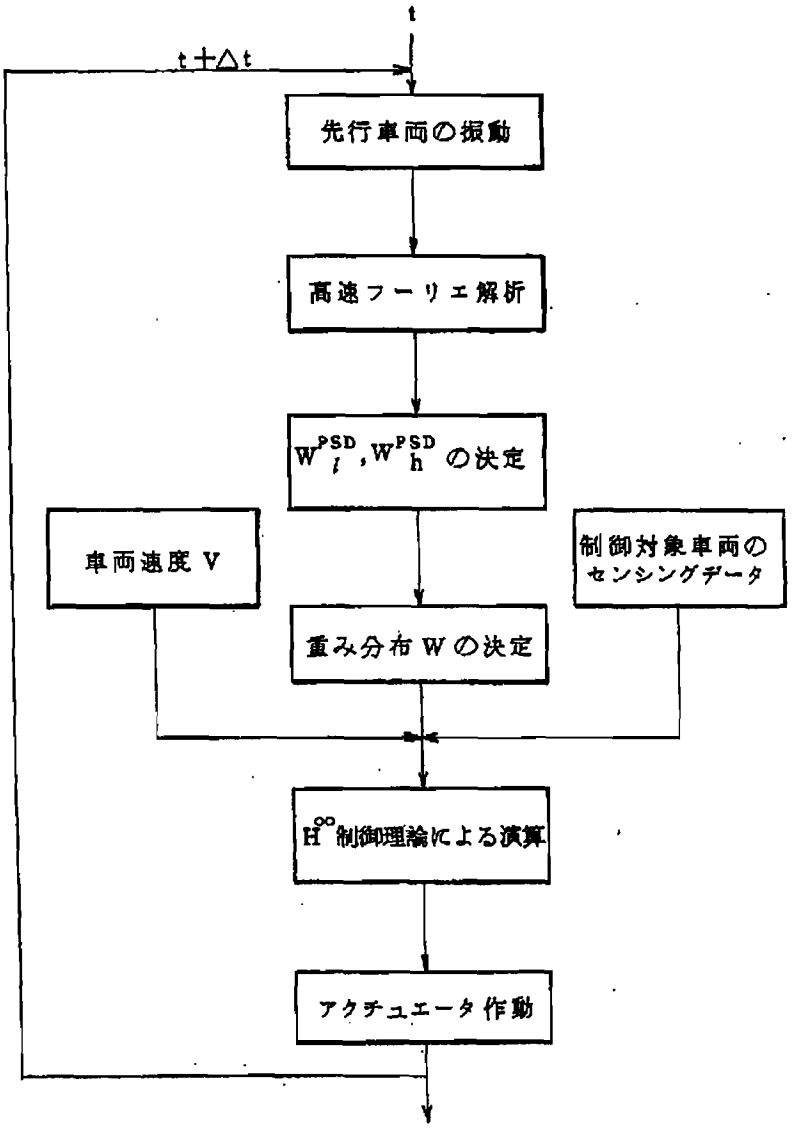
【図6】



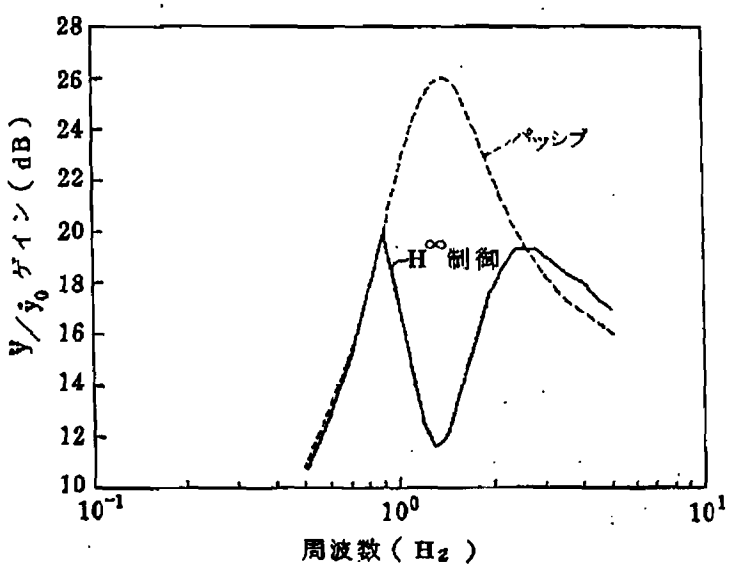
【図9】



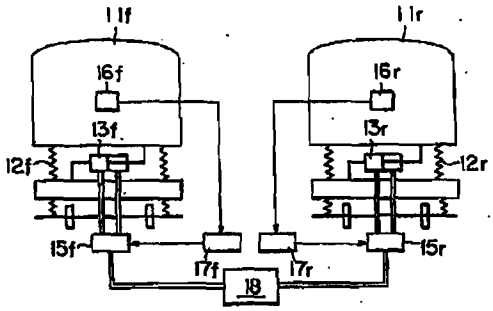
【図8】


t
t＋△t
先行車両の振動
高速フーリエ解析
W_l^{PSD}, W_h^{PSD} の決定
車両速度 V
制御対象車両のセンシングデータ
重み分布 W の決定
H^{∞} 制御理論による演算
アクチュエータ作動

【図１０】



【図１４】



フロントページの続き

(51) Int.Cl.[5]	識別記号	庁内整理番号	F I	技術表示箇所
B60G 17/015		8817－3D		
G05D 19/02		8914－3H		
// F16F 9/50		9240－3J		

(72)発明者　平田　都史彰
大阪府大阪市中央区北浜４丁目５番33号
住友金属工業株式会社内

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 05-343294

(43)Date of publication of application : 24.12.1993

(51)Int.Cl. H01L 21/027
G03F 7/20
H01L 21/68

(21)Application number : 04-176148

(22)Date of filing : 10.06.1992

(71)Applicant : NEC CORP

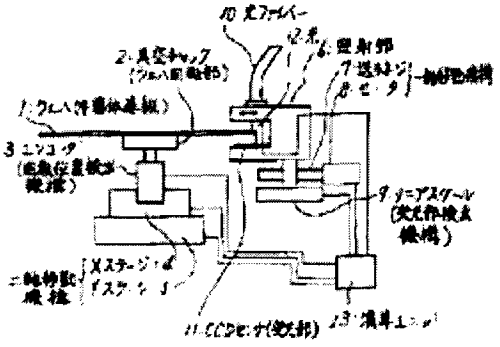
(72)Inventor : FUJIWARA MAKOTO

(54) CONTRACTION PROJECTING EXPOSURE APPARATUS

(57)Abstract:

PURPOSE: To prevent a decrease in processing capacity by simultaneously conducting a peripheral exposure of a wafer and an operation of a prealignment.

CONSTITUTION: An irradiating unit 6 irradiates a wafer 1 with a light 12 from an optical fiber 10. A CCD sensor 11 is provided at a position opposed to the unit 6 to obtain an output responsive to an amount of a light to be shielded. The unit 6 can detect a position by a linear scale 9. The wafer 1 is held and rotated by a vacuum chuck 2. The chuck 2 and the unit 6 are relatively displaced, and the chuck 2 is moved by X-Y stages 4, 5, thereby simultaneously conducting an operation of a prealignment and a peripheral exposure.



(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2005-343294
(P2005-343294A)
(43)公開日　平成17年12月15日(2005.12.15)

(51)Int.Cl.[7]	F I			テーマコード（参考）
B61F 5/24	B61F	5/24	Z	3D301
B60G 17/015	B60G	17/015	A	5H115
B60L 11/14	B60L	11/14	ZHV	

審査請求 未請求　請求項の数 19　OL　（全 21 頁）

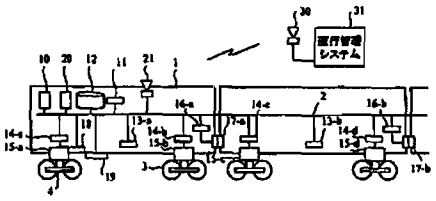
(21)出願番号　特願2004-164756 (P2004-164756)
(22)出願日　平成16年6月2日 (2004.6.2)

(71)出願人　000005108
株式会社日立製作所
東京都千代田区丸の内一丁目６番６号
(74)代理人　100122884
弁理士　角田　芳末
(72)発明者　横須賀　靖
茨城県日立市大みか町七丁目１番１号　株式会社日立製作所日立研究所内
(72)発明者　宮内　努
茨城県日立市大みか町七丁目１番１号　株式会社日立製作所日立研究所内
(72)発明者　前川　景示
茨城県日立市大みか町七丁目１番１号　株式会社日立製作所日立研究所内

最終頁に続く

(54)【発明の名称】適応車両走行制御システム及び適応車両走行制御方法

(57)【要約】
【課題】　本発明の目的は、列車走行等の際に、過去のデータを参照するとともに今後の走行予定経路から、予め制御力特性を最適化したり、さらに、車両重量や気象条件等動的に変化する要因に対しても各種センサ情報を計測することで適応的に最適化したりする、さらに、振動抑制制御した結果改善しない等の状況から装置故障の診断も行うことを目的とする。
【解決手段】　鉄道車両走行のための台車と車両間振動緩衝装置や車両間のダンパの制御力の強さを、車上に搭載したデータベースに蓄積した地図情報と、地図上の地点情報と共に蓄積されている過去の走行履歴から判断できる随時更新可能な最適な前記各制御力の強さ情報と、車上に搭載した位置検知システムが検知する走行地点情報と、ダイヤ情報と、揺れや振動を検知するセンサ情報と、制御力特性の変化を判断する機能から、適宜前記制御力の強さ調整する機能を車両制御システムに搭載する。
【選択図】　図１



【特許請求の範囲】
【請求項１】
車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、
地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、
前記車両上に搭載された位置検知手段と
を有し、
前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整する
ことを特徴とする適応車両制御システム。
【請求項２】
請求項１記載の適応車両制御システムにおいて、
前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項３】
請求項１記載の適応車両制御システムにおいて、
前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項４】
請求項１～請求項３のいずれか一つに記載の適応車両制御システムにおいて、
前記車両上に気象情報を入手する手段と、前記車両の重量を計測する手段と、前記車両の揺れ及び振動を検知する揺れ及び振動検知手段とを搭載し、
前記検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積すると共に、
前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項５】
請求項４記載の適応車両制御システムにおいて、
前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有する
ことを特徴とする適応車両制御システム。
【請求項６】
請求項４または請求項５のいずれか一つに記載の適応車両制御システムにおいて、
前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、
前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新する
ことを特徴とする適応車両制御システム。
【請求項７】
請求項１～請求項６のいずれか一つに記載の適応車両制御システムにおいて、

前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載する
ことを特徴とする適応車両制御システム。
【請求項８】
車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、
地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、
前記車両の位置を検知する位置検知手段と、
気象情報を入手する手段と、
前記車両の重量を計測する手段と、
前記車両の揺れ及び振動を検知する揺れ及び振動検知手段と
を前記車両に搭載し、
前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整すると共に、
前記気象情報を入手する手段、前記車両の重量を計測する手段、前記揺れ及び振動検知手段で検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積し、
前記データベースに蓄積された前記位置検知手段が検知する走行地点情報に関連付けられた前記検知された各情報を、地上の統合システムに送信する通信手段を設け、
前記地上の統合システムでは、複数の前記車両からの情報が統計処理され、その結果が前記通信手段を通じて前記車両に返信される
ことを特徴とする適応車両制御システム。
【請求項９】
請求項８記載の適応車両制御システムにおいて、
前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整する
ことを特徴とする適応車両制御システム。
【請求項１０】
請求項８または請求項９のいずれか一つに記載の適応車両制御システムにおいて、
前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有する
ことを特徴とする適応車両制御システム。
【請求項１１】
請求項８～請求項１０のいずれか一つに記載の適応車両制御システムにおいて、
前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、
前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新する
ことを特徴とする適応車両制御システム。
【請求項１２】
請求項８～請求項１１のいずれか一つに記載の適応車両制御システムにおいて、
前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載する
ことを特徴とする適応車両制御システム。
【請求項１３】
車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段を有し、
データベースに地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とを蓄積し、

前記車両上で検知される走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整する
ことを特徴とする適応車両制御方法。
【請求項１４】
請求項１３記載の適応車両制御方法において、
前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御方法。
【請求項１５】
請求項１３記載の適応車両制御方法において、
前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、
前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整する
ことを特徴とする適応車両制御方法。
【請求項１６】
請求項１３～請求項１５のいずれか一つに記載の適応車両制御方法において、
前記車両上の気象情報と、前記車両の重量と、前記車両の揺れ及び振動とを検知し、
前記検知された各情報を前記走行地点情報と関連付けて前記データベースに蓄積すると共に、
前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整する
ことを特徴とする適応車両制御方法。
【請求項１７】
請求項１６記載の適応車両制御方法において、
前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する
ことを特徴とする適応車両制御方法。
【請求項１８】
請求項１６または請求項１７のいずれか一つに記載の適応車両制御方法において、
前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理し、
前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新する
ことを特徴とする適応車両制御方法。
【請求項１９】
請求項１３～請求項１８のいずれか一つに記載の適応車両制御方法において、
前記車両が複数を連結して編成されているときは、少なくとも前記制御力調整手段とデータベースとを各前記車両ごとに搭載し、
前記走行地点情報の検知を各前記車両ごとに行う
ことを特徴とする適応車両制御方法。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、鉄道車両や路線バス等において、路線を走行するときの揺れや振動を抑制するための抑圧制御力を適応的に最適化して制御を行う適応車両走行制御システム及び適応

車両走行制御方法に関する。

【背景技術】

【０００２】

近年のＩＴ（インフォメーションテクノロジー）化の進展や処理装置の高速化で、列車や航空機、自動車にも高速なネットワークや、高速なマイクロ処理装置が搭載されるようになってきている。また、このような機能を利用して、列車走行時に旅客に対して様々な情報を提供するシステムや、振動や揺れが少ない快適な走行制御が実現されるようになってきている。

【０００３】

ＩＴ技術を用いた電車としては、すでに技術の開示されたものがあり、駅案内情報や広告情報を表示するための表示装置が、扉の上部に取り付けられたりしている。また、車上ＬＡＮを用いて、車上機器の診断なども行っている（例えば、非特許文献１参照。）。

【０００４】

さらに、揺れや振動を低減する技術が開示されているものもあり、車上に路線情報を保持し、ＧＰＳ（Global Positioning System)等で位置を検知し、軌道の凹凸やトンネル走行時の揺れの軽減を図る技術が示されている（例えば、特許文献１、２、３参照。）。

【０００５】

以上の処理は、演算処理装置の性能向上やネットワーク通信技術の発達に伴って、列車での旅行をより快適なものにするための技術開発がされてきた成果である。

【０００６】

特に、列車走行時の揺れの低減に関しては、振動吸収装置自体の改良も続けられ、コイルや板バネ装置による振動吸収機構から、空気バネによる振動吸収機能の改善へと機構自体の改善も進んでいる。また加速時や減即時のショックの緩和もできるＶＶＶＦ（Variable Voltage Variable Frequency）制御や、一段ブレーキ制御のＡＴＣ（Automatic Train Control）等も実現されており、滑らかな加減速制御も実現されてきている。

【０００７】

さらに、カーブ走行時の乗り心地向上策として、振り子制御システムも開発され、カーブ走行時に車体をカーブの内側に傾ける制御等も行われるようになってきている。

【０００８】

【特許文献１】特公平５-８０３８５号公報

【特許文献２】特開２００３－２３７５７３号公報

【特許文献３】特開平８－２０７７６５号公報

【非特許文献１】鉄道技術連合シンポジウム予稿集 「列車内情報サービス提供システムの開発」 p.５８３～５８４ 平成１４年

【発明の開示】

【発明が解決しようとする課題】

【０００９】

本発明は、主として乗り心地に大きな影響を与える、走行時の不快な揺れや振動を適応的に低減することを目的としている。これに対して、前記従来技術では過去の走行履歴を参照してより現在の状態に適した制御の実現や、現在の走行環境に対応して適応制御するという点で配慮に欠けていたものである。

【００１０】

すなわち、台車のバネの強さや車体間のダンパ等は、走行前に設定されるのが一般的である。これに対し、走行中に強さを変更できる例としては、前記特許文献３に開示された技術があるが、これは明かり区間とトンネル内走行時の振動の違いを事前に仮定して、走行前に乗り心地が良くなる強さを設定し、走行地点を検知して変更する方式を開示するに留まっている。このため、走行途中、事前に仮定した条件と大きく離れていても、その乖離を検知して走行しながら制御の強さを適応的に最適化することはできない。

【００１１】

なお、仮定した条件とずれる要因としては様々で、例えば、各車両の乗客数の違いでも

車両重量や車両の重心位置が変化するので、最初に仮定した車両状況からズレが生じる。また車両が走行すれば機械的に必ず疲労するので、バネ定数や車両自体の機械的強度や剛性が変化する。これに対して、機械的メンテナンスは必ず行われているが、全てが規定どおりの正確な値にメンテナンスされるとは限らない。

【００１２】

さらに、軌道の状態も時間と共に変化するし、列車の走行も障害などの影響で、常に設定されたランカーブに従って走れるとは限らないので、軌道の状態と走行速度の関係で揺れの違いが発生することも考えられる。また、車両形状、例えば、先頭車、中間車、モータ車、パンタ付き車両、後尾車両等でも走行中の揺れや振動が異なることが考えられる。なお、列車は、通常往復運転するので、往路では先頭車だったものが、復路では最後尾車両になる。また分割併合運転なども運用としてある。

【００１３】

また、走る路線は、現状の鉄道路線を見れば明らかなように、盛土や高架橋等で路盤を敷き、トンネルやカーブ、坂道、鉄橋などが様々に組み合わされて、形成されることが普通である。これら路線状況の変化も、走行時の揺れに対して、一般的に異なる影響を与える。なお、軌道の状態は、前述したように時間と共に変化するので、最適な振動抑制制御特性も変化することが考えられる。さらに、走行しているときの自然条件、特に風雨等は、走行時の揺れや振動の特性に影響を与える。

【００１４】

さらに、車両の制御の変化の影響も考えられる。例えば、加速やブレーキ時に、制御時のショックが発生することがある。ブレーキ制御は、回生ブレーキや、ブレーキシューによる機械的ブレーキ等様々なブレーキ機構を用いる形態がでてきており、これらの制御のしかたでも、ショックの大きさが変化する。

【００１５】

これらダイナミックに変化する要因に対しても、その走行条件の違いを検知して、本発明は、常に最適に揺れや振動を抑圧するように、台車のバネ強度や、車体間ダンパの制御条件を適応的に最適化できるシステムを提供することを目的とする。

【課題を解決するための手段】

【００１６】

上記課題を解決し、本発明の目的を達成するため、請求項１に記載された発明は、車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、前記車両上に搭載された位置検知手段とを有し、前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整するようにしたものである。

【００１７】

また、請求項２に記載の発明による適応車両制御システムは、前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。

【００１８】

請求項３に記載の発明による適応車両制御システムは、前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。

【００１９】

請求項４に記載の発明による適応車両制御システムは、前記車両上に気象情報を入手す

る手段と、前記車両の重量を計測する手段と、前記車両の揺れ及び振動を検知する揺れ及び振動検知手段とを搭載し、前記検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積すると共に、前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整するものである。

【００２０】

請求項５に記載の発明による適応車両制御システムは、前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有するものである。

【００２１】

請求項６に記載の発明による適応車両制御システムは、前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新するものである。

【００２２】

請求項７に記載の発明による適応車両制御システムは、前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載するものである。

【００２３】

さらに、本発明の目的を達成するため、請求項８に記載された発明は、車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段と、地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とが蓄積されたデータベースと、前記車両の位置を検知する位置検知手段と、気象情報を入手する手段と、前記車両の重量を計測する手段と、前記車両の揺れ及び振動を検知する揺れ及び振動検知手段と　を前記車両に搭載し、前記位置検知手段が検知する走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整すると共に、前記気象情報を入手する手段、前記車両の重量を計測する手段、前記揺れ及び振動検知手段で検知された各情報を前記位置検知手段が検知する走行地点情報と関連付けて前記データベースに蓄積し、前記データベースに蓄積された前記位置検知手段が検知する走行地点情報に関連付けられた前記検知された各情報を、地上の統合システムに送信する通信手段を設け、前記地上の統合システムでは、複数の前記車両からの情報が統計処理され、その結果が前記通信手段を通じて前記車両に返信されるようにしたものである。

【００２４】

また、請求項９に記載の発明による適応車両制御システムは、前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整するものである。

【００２５】

請求項１０に記載の発明による適応車両制御システムは、前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発する警告手段を有するものである。

【００２６】

請求項１１に記載の発明による適応車両制御システムは、前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理する統計処理手段を有し、前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新するものである。

【００２７】

請求項１２に記載の発明による適応車両制御システムは、前記車両が複数を連結して編成されているときは、各前記車両ごとに、少なくとも前記制御力調整手段とデータベースと位置検知手段とを搭載するものである。

【００２８】
さらに、本発明の目的を達成するため、請求項１３に記載された発明は、車両走行のための台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さを調整する制御力調整手段を有し、データベースに地図情報と、前記地図上の地点情報と共に蓄積されている過去の走行履歴から導出される最適な前記各制御力の強さ情報とを蓄積し、前記車両上で検知される走行地点情報と前記データベースに蓄積された最適な前記各制御力の強さ情報とに基づいて前記各制御力の強さを適宜調整するものである。
【００２９】
また、請求項１４に記載の発明による適応車両制御方法は、前記車両が鉄道車両である時には、前記車両が走行するダイヤ情報と前記車両が以後に走行する予定の経路の線路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。
【００３０】
請求項１５に記載の発明による適応車両制御方法は、前記車両が自動車車両である時には、前記車両が走行する経路の情報と前記車両が以後に走行する予定の経路の道路の形状とを参照し、前記台車と車両間の振動緩衝装置及び／または車両間のダンパ装置の制御力の強さの変更の必要性が予測された区間に前記車両が進入する以前に、予め前記各制御力の強さを調整するものである。
【００３１】
請求項１６に記載の発明による適応車両制御方法は、前記車両上の気象情報と、前記車両の重量と、前記車両の揺れ及び振動とを検知し、前記検知された各情報を前記走行地点情報と関連付けて前記データベースに蓄積すると共に、前記車両の揺れ及び振動が許容値を越えたときに、前記車両の揺れ及び振動の検出状況を分析して前記各制御力の強さを調整するものである。
【００３２】
請求項１７に記載の発明による適応車両制御方法は、前記各制御力の強さを調整しても前記車両の揺れ及び振動が許容値を越えるときは、機器故障の可能性を判断して警告を発するものである。
【００３３】
請求項１８に記載の発明による適応車両制御方法は、前記データベースに蓄積された前記検知された車両の揺れ及び振動の情報を統計処理し、前記車両の揺れ及び振動が許容値を越えたときに、前記統計処理の結果に基づいて前記データベースに蓄積された前記最適な各制御力の強さ情報を更新するものである。
【００３４】
請求項１９に記載の発明による適応車両制御方法は、前記車両が複数を連結して編成されているときは、少なくとも前記制御力調整手段とデータベースとを各前記車両ごとに搭載し、前記走行地点情報の検知を各前記車両ごとに行うものである。
【発明の効果】
【００３５】
本発明によれば、列車走行等の際に過去のデータを参照するとともに、今後の走行予定路線を見て、予め制御力特性を最適化できる場合は、揺れや振動を抑制するように走行位置に合わせて前もって制御力を最適化し、動的に変動する要因に対しては各種センサ情報から情報を入手し、動的に最適化できるようになる。
【００３６】
したがって、これらの制御により、列車等が走行中、概ねの走行環境に合わせた揺れや振動の抑制ではなく、走行位置によって適応的に抑制できるので、常に快適な乗り心地を提供できるようになる。また、揺れや振動を抑制しようとして制御した結果、改善しない等の状況から、装置の故障かもしれないなどの警報情報も出力できるので、メンテナンス作業の効率化もできるようになる。

【発明を実施するための最良の形態】
【００３７】
すなわち本発明においては、列車走行等の際に、過去のデータを参照するとともに今後の走行予定経路から、予め制御力特性を最適化し、さらに、車両重量や気象条件等動的に変化する要因に対しても各種センサ情報を計測することで適応的に最適化する。さらに、振動抑制制御した結果改善しない等の状況から装置故障の診断も行うという目的のシステムを、ＩＴ技術と発達した制御処理プロセッサ技術を用いて効率的に実現した。
【実施例】
【００３８】
以下、本発明の一実施例を説明する。図１は、本発明の基本構成の一例を示したものである。図１において、鉄道車両１は、複数の車両が連結された場合を示しており、各車量に装備する装置は同様の構成になるので、３両目以降は省略してある。
【００３９】
まず、車両内に装備する装置構成を説明の後、各装置が連携して動作し、本発明が目的とする適応制御システムの動作について説明する。各装置は、車両内に引きとおした車上ＬＡＮ２を通して接続されている。但し、ここでは一例としてＬＡＮを使用した例を示しているが、一対一の制御線で接続しても、本発明が目的としている制御機能を実現することは可能である。
【００４０】
台車４は、駆動台車であれば車輪３を駆動して列車を走行させる。通常、鉄道列車はモータ駆動車両と、駆動されない付随車両が組み合わされて構成される。機関車で牽引されるタイプの鉄道列車は、機関車と付随車両から構成される。走行中の揺れや振動をできるだけ車両に伝えないように、該台車４と車両の間には空気バネなどの台車と車両間振動緩衝装置１５（ａ，ｂ，ｃ，ｄの枝番は、同じ機能であるが各台車に分かれて装備されていることを示すために使用）が設備されている。
【００４１】
該台車と車両間振動緩衝装置１５の動作を制御する装置が、バネ力調整制御装置１４（枝番ａ，ｂ，ｃ，ｄは、同じ機能であるが各台車に分かれて装備されていることを示すために使用）である。該バネ力調整制御装置１４は、車上ＬＡＮ２を通して列車走行制御装置１０に接続されている。該列車走行制御装置１０からの指令に従い、バネ力調整制御装置１４で台車と車両間振動緩衝装置１５のバネ力を適切に調整する。
【００４２】
１両単独で走行するのでなければ、図１に示すように車両を接続して走行する。本発明では、列車間で異なる揺れや振動の影響を抑制するために、車両間ダンパ装置１７を用いる。該車両間ダンパ装置１７（枝番ａ，ｂは、同じ機能であるが各車両間に分かれて装備されていることを示すために使用）を制御する装置が、車両間ダンパ力制御装置１６（枝番ａ，ｂは、同じ機能であるが各車両間に分かれて装備されていることを示すために使用）である。
【００４３】
位置検知装置１１は、当該列車の走行位置を検知するための装置である。位置検知機能を実現する装置としては、ＧＰＳ（Global Positioning System）の利用や、地上側に地点検知用のタグなどを設置しそのタグ情報と移動距離から位置を検知する装置、或いは、特徴的な目印を認識して位置を特定する装置等、幾つか実現手法が考えられるが、本発明では適切な位置検知手法を選択すればよく、特定の位置検知装置の使用に限定されるものではない。
【００４４】
車上ＤＢ１２は、路線の地図情報や物理的な形状、即ちトンネルやカーブ、高架などの路線情報を蓄積すると共に、過去の走行位置と揺れや振動の測定状況や車両の編成状況、現在の台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力の設定値等を蓄積したり、現在の走行の揺れや振動の状況を位置検知装置１１の位置検出結果と共に蓄積し

たりするものである。センサ類１３は、走行中の揺れや振動などを検知するための装置であり、図２を用いて後ほど構成例を説明する。

【００４５】

ブレーキ制御装置１８やモータ制御装置１９は、文字通り列車を止めたり走行させたりするブレーキやモータの動きを制御するものであり、列車走行制御装置１０からの指令で、制御を実行する。本図では、図面の見易さを考慮して、便宜上ブレーキ制御装置１８やモータ制御装置１９は一組のみ示しているが、列車編成を考慮して必要数だけ装備されるものである。

【００４６】

入出力装置２０は、例えば、現在のバネ力調整制御装置１４や車両間ダンパ力制御装置１６の制御の強さやセンサ類１３の検出状況を監視したり、これから走行する路線データ（固定的なカーブや坂道、トンネル、駅の配線状況、ダイヤに従った駅での到着番線など）の入力機能を必要に応じて提供したりする。地上車上間通信装置２１は、走行予定の線区の気象状況やダイヤの乱れ状況等を、地上通信装置３０と交信して運行管理システム３１から取得する通信機能を提供する。

【００４７】

次に走行中、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を適応的に最適化する動作について説明する。

【００４８】

列車の走行は、予め計画されたダイヤに従って走行する。車両の運用については、毎日同じ車両が同じ路線を同じ時間帯に走行するわけではなく、日々割り当てられた計画に従って走行することになる。このため、走行路線が異なれば、分岐やカーブの配線の状況、路盤や線路の凹凸の状況、分岐の状況も異なるし、乗客の数もダイナミックに変化するので車両の重量や重心の位置が異なる。

【００４９】

また、気象条件や、車両や軌道の経年変化やメンテナンスによって、状況は必ず変化する。これら状況の変動要因はあるが、これまでは、技術開発と経験からある条件を仮定して、車両間振動緩衝装置１５や車両間ダンパ装置１７の制御の強さを予め定め、揺れや振動を概ね抑制できるように設定し、乗客の不快感を低減するようにしていた。本発明では、前記のようにダイナミックに変化する走行条件に対応して、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を最適化する動作を実行するものである。

【００５０】

図３を用いて、列車走行制御装置１０で実行する本発明のシステム全体の制御の流れを説明する。

【００５１】

まず処理１０１で、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力をデフォルト値にセットすると共に、該値で正常動作していることを確認する。ここでは入出力装置２０で取扱者が内容を確認し、その設定を変更したい場合は、入出力装置２０から変更要求をセットする。該マニュアル要求があった場合は、マニュアル要求を処理１０２で処理し、車上ＤＢ１２に要求値をセットする。次に各センサからの情報、即ち、処理１０３で位置情報、処理１０４でその他のセンサ情報を入力する。

【００５２】

処理１０４で入力するセンサ情報としては、図２にセンサ類１３の構成の一例を示すように、重量センサ５１、振動センサ５２、加速度センサ５３、ジャイロ５４、ヨーレイトセンサ５５等から出力される情報である。これらの情報から、現在の車両の状況を検知する。次に処理１０５で、車上ＤＢ１２の情報を参照し、マニュアル優先で台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力をセットしたいという要求があった場合は、マニュアルセット情報を参照し、該値に従って制御力をセットする。

【００５３】

もし、自動セット要求であれば、現在のセンシング情報を参照し、過去の制御状況から

学習して最適制御力として蓄積されている情報を検索し、該情報に従って自動的に、車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力をセットするように、バネ力調整制御装置１４と車両間ダンパ力制御装置１６に命令を出力する。この制御の手法については、後ほどさらに詳しく説明する。

【００５４】

処理１０６では、揺れや振動の計測値を、現在の制御力の値や、走行位置、速度、車両重量などと共に車上ＤＢ１２に蓄積する。その内容は、例えば図５の表１に示すようなものであり、後ほど内容について説明する。処理１０７では、揺れや振動の状況を予め許容範囲として設定していた値と、現状の観測値を比較して乗り心地評価を行う。処理１０８で、その評価値が許容範囲を逸脱しているかどうか判定し、逸脱していなければ処理１０２からの処理を繰り返す。逸脱していた場合は、処理１０９を実行する。

【００５５】

まず処理１０９で、逸脱した揺れや振動の原因を分析する。図４を用いて原因分析処理について説明する。最初に、処理１５１でセンサ類１３の出力を取り込む。センサ類１３の構成の一例は図２に示されている通りである。重量センサ５１は、台車４に取り付けられている前記台車と車両間振動緩衝装置１５に接続され、緩衝用のバネの沈み込みの状況や、装置にかかる圧力を計測する。

【００５６】

この重量センシング情報を列車走行制御装置１０に送り、該情報から、該列車走行制御装置１０で、現在の重量の見積と車両の形状（座席の数や車両の構造等）を考慮し、何人ぐらいの乗客が乗っていて着席客と立ち客の状況推定も行い、車両の重心の高さも推定する。振動センサ５２は、細かな周期の振動、例えば振動の周期のピークが数Hz以上の縦揺れや横揺れを計測し、各周波数帯での振幅を計測する。加速度センサ５３やジャイロ５４では、変化の周波数が数Hz以下の低い帯域での変化量を計測し記録する。

【００５７】

ヨーレイトセンサ５５では、車両の進行方向に対する横の捻れ動作を計測し、記録する。図２では、列車走行時の揺れや振動を計測したり、その要因を特定するために計測する装置として、重量センサ５１、振動センサ５２、加速度センサ５３、ジャイロ５４、ヨーレイトセンサ５５を例示したが、振動や揺れの計測で不要なものは当然取り付ける必要は無いし、さらに詳しく計測したければ必要に応じて計測装置を追加すればよい。

【００５８】

例えば、揺れや振動に影響を及ぼす風雨の影響も車上単独で計測したければ、風力計や雨量計を装備すればよいし、画像計測などで線路の状況や振動の状況を計測したければ、計測用のカメラを装備してもよい。特に図示していないが、本例では現状の気象観測システムを有効に利用することを考え、気象に関する情報は地上側に設備されているセンサで計測した情報を、図１に示した運行管理システム３１から無線通信で送信してもらうことを仮定している。本発明のシステムとしては、必要なセンシング情報をシステムに適した形態で、入手すればよい。

【００５９】

処理１５２では、これら取り込んだセンシング情報と、現状の走行条件として仮定した状況を詳細に比較検討する。走行条件として仮定する項目としては、車両重量、車両の重心の位置、風雨の状況、走行路線の形状（トンネルや明かり区間等の違い）と線路の整備状況、スラブやバラスト、高架や盛土など軌道の建設状況等である。

【００６０】

走行条件として仮定した項目と現状の差異は、１）車両重量などは、重量センサ５１の出力と設定値との比較で乖離を判定、２）車両の重心の位置も車両の形状と推定重量から、着席乗客や立ち乗客を見積もって乖離を推定、３）自然条件である雨や風の状況は、運行管理システムから受信した値と比較することで乖離を判断、４）走行路線の形状や軌道の建設状況は走行ダイヤと位置検知情報、及び過去の走行履歴を参照することで仮定した走行環境との乖離を判断する。

【００６１】
処理１５３で、前記乖離判定と揺れの特徴から最も揺れや振動が増加した原因として大きいと判断できるものから順にプライオリティをつける。例えば、仮定した重量よりも重かったことが原因である場合は、軌道環境の良し悪しに敏感に反応するようになるので、加速度センサの変化の度合いが大きかったり、振動センサの周期と振幅が増大したりする現象が、乗客数の変動が無ければ、走行している間定常的に観測されることになる。風が強い場合は、特定の方からの比較的低周波の揺れが観測されることから判断する。
【００６２】
軌道状況が変化した場合は、何度か走行して同じ地点で同じような揺れや振動が観測されるので、蓄積したデータの解析から判断できる。この路線状況の変化に起因すると判断された場合は、図３の処理１０５で予め設定するために参照するＤＢへ反映し、走行前に自動的に調整できるようにする。
【００６３】
制御機能が劣化している場合は、要因として特に揺れや振動抑制が劣化するとは考えられないときに、定常的に以前の履歴と比較して揺れや振動の状況が劣化している場合に推定される原因となる。さらに制御力を変えるように指示を出しても、状況が変化しない場合は、機器故障という判断もできる。このような推定論理を用いて、処理１５３で判定する。
【００６４】
処理１５４では、処理１５３でプライオリティを判断して対策したにもかかわらず状況が改善しなかった場合に、順次対策をするための対策履歴を参照して、今回行うべき対策の選択をする。次に判断１５５で、考えられる全ての対策をしても状況が改善しなかったかどうかを判断し、改善していなかった場合は、処理１５６に分岐し、デフォルトの制御力に設定を指示して、未知の揺れや振動要因であったことを記録し、機器劣化や故障の可能性も有りその判断結果も記録する。
【００６５】
まだ全ての制御対策をしていない場合は、判断処理１５７に分岐し、そこで、制御力調整処理として最初の処理かどうか判断して、最初の処理であれば処理１５９の対策処理を実施する。最調整処理であれば、処理１５８で前回の設定をリセットし、今回の対策処理を有効にするように指示して揺れや振動の要因分析処理を完了させる。即ち、図３に示す処理１０９の処理が完了する。
【００６６】
処理１０９で、対策処理が決定されるので、その対策指示を処理１１０～処理１１４で実施する。処理１１０は、逸脱原因が、前提とした車両重量からの乖離であると判断された場合の対策である。該処理１１０では、車両重量が現状の制御力に設定した前提重量より重いために揺れや振動が増加したとの判定結果のときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を硬くするように変更する指示を出力する。
【００６７】
一方、車両重量が現状の制御力に設定するために前提とした重量より軽いために揺れや振動が増加したとの判定結果であったときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を柔らかくするように変更する指示を出力する。
【００６８】
処理１１１は、逸脱原因が前提とした自然環境からの乖離であると判断された場合の対策である。処理１１１では、例えば、風向風力が現状の制御力に設定した前提重量より大きいために揺れや振動が増加したとの判定結果のときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を硬くするように変更する指示を出力する。さらに、車両間ダンパ力制御装置１６に対して、風上側の車両間ダンパ装置１７の制御力を強くするように指示を出力する。
【００６９】

処理１１２は、逸脱原因が前提とした軌道の状況からの乖離である判断された場合の対策である。該処理１１２では、軌道の状況が現状の制御力に設定した前提軌道条件よりの劣化、例えば線路表面の凹凸や、線路の左右の曲がりが増大したために揺れや振動が増加したとの判定結果であったときには、その凹凸や左右の線路の曲がりの周期や大きさに適合したバネ力になるように、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力の調整指示を出力する。

【００７０】

アクティブに車体を傾ける制御として列車では、特にカーブ通過時の乗り心地向上対策として、車体の振り子制御が行われる場合があり、既に実現されている。この制御は、一般的にダイヤを参照し現在位置を検出しながら路線データを参照して、カーブを認識すると車体をカーブの内側に傾斜させる制御が行われる。本発明では、該振り子制御を実施するものではないが、振り制御機構が搭載されている車両では、その特性も認識して協調制御することができる。

【００７１】

すなわち本発明において、例えば、設定速度より高速でカーブすれば推定過重が増加するので、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力を硬くするように指示するし、振り子制御が何らかの原因で計画どおり実施されない場合は、遠心力の大きさをジャイロ５４や加速度センサ５３から検知し、台車と車両間振動緩衝装置１５の制御力を硬くするように制御する。

【００７２】

処理１１３は、逸脱原因が前提とした制御力指示に対して予定した制御力との乖離がある場合の対策である。該処理１１３では、制御力指示に対して予定した制御力より不足したために揺れや振動が増加したとの判定結果であったときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力をさらに硬くするように変更する指示を出力する。また、車両間ダンパの制御力が不足していた場合は、車体間ダンパ力制御装置１６に対して、車両間ダンパ装置１７の制御力をさらに強くするように指示を出力する。

【００７３】

一方、制御力指示に対して予定した制御力より超過したために揺れや振動が増加したとの判定結果であったときには、バネ力調整制御装置１４に対して、台車と車両間振動緩衝装置１５の制御力をさらに柔らかくするように変更する指示を出力する。また、車両間ダンパの制御力が超過していた場合は、車体間ダンパ力制御装置１６に対して、車両間ダンパ装置１７の制御力をさらに柔らかくするように指示を出力する。

【００７４】

処理１１４は、逸脱原因を推定して対策をしたが、処理に作りこんだ全ての対策を行っても結局改善が見られなかった場合の処理である。この場合は図４の処理１５６の結果に相当する場合で、デフォルトの制御力に設定を指示して、未知の原因で揺れや振動があったことを記録し、機器劣化や故障の可能性も有り、その判断履歴や結果を蓄積データ用に加工する。

【００７５】

これら、処理１１０から処理１１４の何れかの処理を実行した後、処理１１５で制御実施履歴と結果を車上ＤＢ１２に格納後、処理１０２に戻り処理を繰り返す。以上の処理について走行中周期的に実行を続けて、機器故障や未知の揺れや振動等の要因が検知されない限り、揺れや振動に対して不快感を大きくしないような乗り心地環境を提供する。

【００７６】

さらに図５の表１には、制御した処理周期ごとに処理１１５でデータを車上ＤＢ１２に蓄積し、履歴を残すためのデータフォーマットの一例を示している。表の縦列方向のひとかたまりが、一回の周期で記録するデータ例である。表の左端に項目を示している。

【００７７】

制御周期として、表の最上段に示すように、仮にｎ番目からの例を示している。次の列

がｎ＋１番目、次ぎがｎ＋２番目で、ここでは５秒間隔で記録する場合を示しているが、該記録周期は、制御の実態を考慮し、例えば、定量的な情報がまだ確立されていない場合は、車上ＤＢの容量を大きくし、記録周期を短くして詳細な情報を収集したり、一方、十分に路線情報が集まり変化が少なければ記録周期をのばし、車上ＤＢ容量を節約したりすることもできる。

【００７８】

実情に合わせて、記録周期と車上ＤＢ容量を決定し、制御を続ける間、記録を継続することを右端の列は示している。項目としては、搭載するセンサ情報に関係して、列車番号や編成番号、時刻やそのときの位置に関連付けて、揺れや振動を方向別に、振幅、周波数、加速度、ヨーレート、そのときの制御力の強さ、列車速度、推定重量、気象上のデータを設定している。この項目は、当然搭載するセンサの種類、観測する項目の違いにより変化する。ここでは、図１に例示したシステムを対象に例示している。

【００７９】

図６は、列車の走行環境をイメージして、どのように制御されるか状況を表示したものである。３両編成の列車を、Ａ列車２０１、Ｂ列車２０２、Ｃ列車２０３で示している。線路の配線２００は、各一本の線が各列車の走る線路を示していて、駅中間部分は複線である。各列車の進行方向は列車に付属させた矢印で示している。駅はＡ駅２０５とＢ駅２０６の２駅のみを示し仮想的な路線である。

【００８０】

ここに示すように、ダイヤと車両運用計画が決まれば、これから走行する路線の環境を予め知ることができ対応した最適制御力を走行地点に関連付けて各列車に設定できる。即ち、どこで分岐し、トンネルがどこにあり、どのような軌道環境、例えばカーブや高架橋、スラブ軌道やバラスト軌道などの状況、また、過去の走行データの蓄積からどのように線路環境が変化しているかなどの情報から、走行位置に関連付けて予め走行前に最適な制御力を図３の処理１０５でセットでき、これら条件に対しては予め適切な制御環境を整える。

【００８１】

一方、動的な条件、例えば、Ａ駅、Ｂ駅とも４本の番線があるが、Ａ列車は、Ａ駅に停車中に乗客の乗り込みで、重量が増えたと仮定する。すると、図３の処理１１０が動作し、台車と車両間振動緩衝装置１５の制御力を硬く変更して、走行をすることになる。また、Ｃ列車は、ダイヤからＢ駅で分岐してカーブして行く方の番線に到着することになっている例を示している。

【００８２】

図では分岐線路上に在線している例であるが、前記処理１０５で走行環境に起因して制御力を設定する機能からこのように分岐する部分に入る前に、この先に分岐があり横方向の揺れが大きいことが分かるので、予め、分岐の手前で、台車と車両間振動緩衝装置１５や車体間バンパ装置１７を硬めに設定して揺れを押さえるように制御する。

【００８３】

また、線路部２０４は、過去の走行から線路の歪みが大きいと判断されている部分を示しており、Ａ列車は進行と共に、この線路部２０４に進入する前に、最適な制御力に台車と車両間振動緩衝装置１５を調整する。Ｂ列車２０２は、カーブを走行中の状態を示している。ここで仮にＢ列車に適切な振り子装置が装備されていないとすると、遠心力でカーブの外側に車体が傾斜しようとする。この傾斜を押さえるために、カーブ部分に進入する前に進行方向左側の車両間振動緩衝装置１５の制御力を硬めにしたり、車体間バンパ装置１７も硬めに設定したりする。

【００８４】

一方、Ｂ列車に振り子装置が装備されていた場合は、振り子装置の特性に合わせて揺れや振動が抑制されるように制御するか、通常の直線走行時の制御力のままで走行することになる。このように、過去のデータやセンサ類１３の情報を用いて適応的に台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を調整して、揺れや振動を抑制して乗

り心地を改善する。

【００８５】

車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力の強さは、列車単位で見ると当該列車での平均的な制御となるが、車上ＤＢ１２も車両単位にデータを蓄積しておき、車両単位で図３に示した処理を実行すれば、よりきめ細かな制御ができる。さらに、列車の編成状況をセットすれば、編成の連結状態も考慮して制御もできる。この状況を、図７を用いて説明する。

【００８６】

ここまでは、鉄道車両１の形状や走行時の状態について言及しなかったが、鉄道車両は各車両ごとに若干形状や機能も異なっていることが普通である。図７は４両編成の仮想的な車両編成例で、矢印で進行方向を示す。通常電車などは、ある決まった編成単位で運用されることが普通であり、編成の両端車両２５０と２５４には運転席２５５（枝番ａ，ｂは、同じ機能であるが各々の車両間に分かれて装備されていることを示すために使用）が設備される。

【００８７】

モータ制御装置１９は、全車両に装備されることもあるが、図に示すように編成内のある車両２５１に装備され、その他の車両には取り付けられない場合が多い。また、パンタグラフ２５３も装備車２５２にだけに取り付けられ、その他の車両には無いというように、各車両ごとに形状や重量バランスが若干異なっていることが普通である。また、図では進行方向を矢印で示すように図面左側から右側としているが、車両形状が全く同じでも、先頭車と中間車、後尾車とでは受ける風圧の影響が異なってくる。

【００８８】

このため、車両の形状や機能、進行方向を考慮して、図３に示す処理を個々の車両毎に実施し、よりきめ細かな制御も、図１に示す構成で実現できる。即ち、図示するように各車両ごとに取り付けたセンサ類１３からの情報を車両ごとに、列車走行制御装置１０で演算し、出力を各車両ごとに個別に設定することで実現する。また、軌道の歪みや湾曲等でその位置に到達したときに発生する揺れや振動の対策も、各車両毎に該走行環境が劣化している走行位置に入る前に制御力を調整すれば、よりきめ細かな制御が可能になる。

【００８９】

図８は、列車が仮想の線区を走行するときの運転曲線２６０の一例を示している。縦軸が速度で、横軸は位置を示している。Ａ駅を出発した列車がＣ駅方向に走る場合で、当然駅を出発するときに加速をして、Ｂ駅やＣ駅に止まるときに減速をする。しかし、駅間で図示するように、カーブや工事などで速度制限区間２６５がある場合等は、減速を強いられるし、駅間での最高速度も必ず同じというわけではなく、異なることも多い。

【００９０】

図では、加速区間を２６１、２６３で示し、減速区間を２６２、２６４、２６５で示している。まず、加速区間では力行ノッチ制御が入り、減速区間では減速ノッチ制御が入ることになる。低速走行区間では、惰行などを組合せながら目標速度に追従するように制御され、通常あまりノッチ制御は頻繁ではない。このため、加減速区間では、ノッチ変更や加減速のために、列車の前後の加速度でショックを感じることがある。

【００９１】

このショックを緩和するためには、台車と車両間振動緩衝装置１５や車体間ダンパ装置１７の制御力を硬めに設定して、前後の揺れを押さえた方が良い。駅中間の低速走行では、加減速制御は頻繁ではなく、線路の凹凸などの影響を台車と車両間振動緩衝装置１５や車体間ダンパ装置１７で吸収できるように、制御力を弱めに設定した方が良い。このような制御も、図１に示す構成で、ダイヤ情報と、位置検知情報から予め制御可能であり、図３に示す処理１０５で使用する情報として、車上ＤＢ１２に蓄積することで実現する。

【００９２】

図９は、列車走行制御装置１０で実行する車上ＤＢの更新処理の一例を示している。車上ＤＢには走行するごとに、走行中の制御状況とセンサでのセンシング結果が、図５の表

１に示す形で車上ＤＢ１２に蓄積されて行く。走行環境は恒常的に一定と言うわけではなく、線路の状況や路盤の状況等は、時間と共に変化する。このため、当該路線に対して最適な台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力も変化してゆく。

【００９３】

ところで、通常この変化は、気象の変化や車両重量の変化と異なり、ある位置が特定され、また時間的に経年変化というオーダーでゆっくりと変化して行く。一方、メンテナンス工事も行われるので、この場合には路盤や線路の特性がステップ的に変化することが考えられるが、この場合でも走行位置に関連付けてデータを解析することにより、どのように状況が変わったか推測できる。このようなことから、図９に示すように同じ線区を走行したときのデータを何回分か纏めて解析すればその特徴が判断できる。

【００９４】

図では、仮に第ｍ回目の走行データ２７０から、ｍ＋１回目の走行データ２７１、ｍ＋２回目の走行データ２７２、ｍ＋ｋ回目の走行データ２７３を統計処理２７４で処理する例を示している。例えば、ある特定位置の線路が波打ったように表面が劣化したとすると、その位置で特に揺れや振動が大きくなるという走行データが優位的に見られることになるので、その位置を走行する場合は、台車と車両間振動緩衝装置１５や車両間ダンパ装置１７に対して、最適となるように予め当該線区を走行する場合の制御力設定情報２７５を更新する。

【００９５】

このようにして、当該車両が走行した線区に対して、予見できる地点での台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の最適制御を予め随時更新して、適応的に揺れや振動を最適に抑制する。もし当該車両が、初めてその線区を走行する場合は、運行管理システム３１から制御力設定情報２７５を受信するか、入出力装置２０を通して情報をセットしてもらい、その情報を読み込んで、制御力を設定する。

【００９６】

図１０は、地上ＤＢに制御力設定情報２７５を集中して蓄積管理する場合のシステム構成例を示している。即ち、機能的には図１に示したシステムで実現する適応的な揺れや振動の最適低減と同じであるが、予め既知の走行状況に対して走行前に読み込む制御設定情報２７５を地上側ＤＢ３０１に集中管理するシステム構成である。

【００９７】

この場合、車上ＤＢ１２は、地図情報や該地上データベースが受け取った情報を蓄積したり、一連の走行で取得した図５の表１に示した走行データを一時保管したりすることに使用し、該一連の運用で走行した後、或いは走行中に随時運行管理システムに送信し地上側列車走行制御ＤＢ管理装置３０２に伝達する。伝達の手法としては、無線通信を使用することもできるし、ディスクメモリ装置や固体メモリ装置等様々なメディアから、適切な手法から選択して用いればよい。

【００９８】

地上側列車走行制御ＤＢ管理装置３０２は、各走行毎の図５の表１に示す走行データを受け取り、地上側ＤＢ３０１に蓄積し、列車走行制御装置１０で実行する処理と同じように、集中管理している各編成車両単位に地上側ＤＢ３０１の変更処理を実施する。そして、各編成車両単位に変更処理した情報は制御力設定情報２７５と同じ形式で蓄積する。

【００９９】

各情報は、前記同様無線通信や、固体蓄積媒体を通して走行前に車上ＤＢ１２に送られ、列車走行制御装置１０が随時参照し、適切に台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を、過去のデータから参照される範囲では予め調整しておき、稼動中は図３に示した処理と同じ処理を車上の列車走行制御装置１０で実行し、車両重量や気象条件、或いは軌道の状況の変化で揺れや振動の抑制が十分でないと判断した場合は、適応的に台車と車両間振動緩衝装置１５や車両間ダンパ装置１７の制御力を調整して、揺れや振動の抑制を最適化する。

【０１００】

図１のシステム構成でも図１０に示したシステム構成でも、バネ力調整制御装置１４や車両間ダンパ力制御装置１６は、台車と車両間振動緩衝装置１５と車両間ダンパ装置１７に付随して分散配置する構成を示しているが、これらの装置機能を列車走行制御装置１０に集中し、制御出力結果を台車と車両間振動緩衝装置１５と車両間ダンパ装置１７に対して制御線で伝達する構成も実現可能であるし、論理を大規模集積回路化し、台車と車両間振動緩衝装置１５と車両間ダンパ装置１７に組み込んで実現することも可能である。

【０１０１】

すなわち、システム構成として、ブロック構造化を基本にフレキシビリティを優先させるか、システム構成の簡素さを優先させるか、運用を考え適宜最適なシステム構成形態を選択すればよい。

【０１０２】

図１１は、これまで鉄道車両を対象に説明してきたが、それ以外の交通システムへ適用した場合の一例を示したものである。自動車用ナビゲーション装置が広く普及してきて、目的地を設定すると、経路案内をしてくれる機能も実現されてきている。また、自動車ナビゲーション装置は、機能の基本として位置検知機能があり、好みの機能を選択するための入出力装置も備えている。

【０１０３】

この機能を利用すると、これまで説明してきた制御力の最適化機能の実現が自動車でも可能になる。図に示すように、自動車３５０に搭載されたナビゲーション装置３５１があり、その表示部分の拡大図を３５４とする。現在位置３５７と目的地３５８を入力し、経路誘導された結果が、実線で示す３５５であったとする。

【０１０４】

この経路誘導結果と、ナビゲーション装置３５１に接続されたセンサ類１３によって計測された過去の走行結果の揺れや振動の計測結果を保持している車上ＤＢ３６０の情報、或いは、ナビゲーションサービスセンタ等から入手した情報から、路面がいたみ振動が大きくなる道路区間３５６が見つかったとすると、該道路区間３５６に進入する前に、予めショックアブソーバ３５２や３５３の制御力を適切に調整し、揺れや振動を押さえるように制御する。

【０１０５】

車上ＤＢ管理装置３５９は、車上ＤＢ３６０の記録データの更新、例えば、図９に準じて、同じ道路通った時のデータを幾つか集め統計処理して、車上ＤＢ３６０の情報の更新を行う。これらの制御は、ナビゲーション装置３５１の持つ入出力インターフェイスを通して、自動で実施するのか、或いはしないのかなどは、運転者の好みで随時設定できるようにしておくことで、運転者の思考に合わせることもできる。

【０１０６】

さらに、本発明を自動車に応用する場合には、例えば乗り合いの路線バスに適用することにより、鉄道車両の場合とほぼ同等の機能を発揮させることができる。すなわち、このような乗り合い路線バスにおいては、走行する路線が予め設定され、常にその路線に沿って運行されるので、鉄道車両における線路に類似した管理や処理、制御が可能となるものである。

【０１０７】

また乗用車においても、図１０に示すように地上ＤＢを設置して、複数の自動車からの情報を集約することによって、より広範な機能を実現することが可能になる。すなわち、この地上ＤＢには、多数の自動車からの情報を集約することにより、自動車が走行する道路の情報を網羅的に収集することができ、これによって鉄道車両における線路に類似した管理や処理、制御が可能となる。なお、このような地上ＤＢは、タクシー会社等に設けて運用することや、ユーザーが組織を結成して運用することができるものである。

【０１０８】

以上説明したように、本発明により列車走行等の際に、過去のデータを参照するとともに今後の計画走行路線を見て、予め制御力特性を最適化できる場合は、揺れや振動を抑制

するように走行位置に合わせて前もって制御力を最適化し、動的に変動する要因に対しては各種センサ情報から情報を入手し、動的に最適化できるようになる。そして、装置の故障かもしれないなどの警報情報も出力でき、乗り心地を常に最適に保つように制御できると共に、メンテナンス作業の効率化もできるようになる。

【０１０９】

なお本発明は、上述の説明した実施形態に限定されるものではなく、特許請求の範囲の記載を逸脱しない限りにおいて、種々の変形が可能とされるものである。

【図面の簡単な説明】

【０１１０】

【図１】本発明の基本構成を示す構成図である。

【図２】車両に搭載するセンサ類の構成を示す構成図である。

【図３】適応車両走行制御システムのメイン制御フローチャート図である。

【図４】走行車両の揺れや振動の要因分析処理フローチャート図である。

【図５】走行車両の揺れや振動の要因分析処理の説明に用いる表１図である。

【図６】路線をイメージしての揺れや振動の抑制制御の実施例を示す構成図である。

【図７】車両編成の構成例を示す構成図である。

【図８】加減速制御時のショックを低減する制御例を示す構成図である。

【図９】ＤＢの更新制御の模式図である。

【図１０】地上ＤＢ主体の車両制御システムの構成例を示す構成図である。

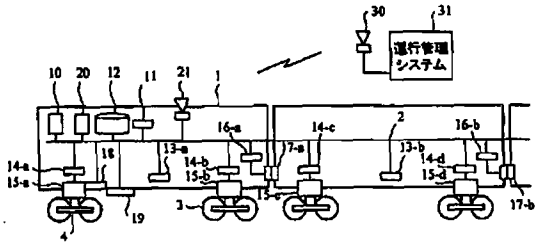
【図１１】自動車を対象にしたシステム構成例を示す構成図である。

【符号の説明】

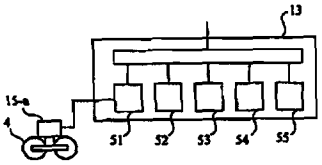
【０１１１】

１…鉄道車両、２…車上ＬＡＮ、３…車輪、４…台車、１０…列車走行制御装置、１１…位置検知装置、１２…車上ＤＢ、１３…センサ類、１４…バネ力調整制御装置、１５…台車と車両間振動緩衝装置、１６…車両間ダンパ力制御装置、１７…車両間ダンパ装置、１８…ブレーキ制御装置、１９…モータ制御装置、２０…入出力装置、２１…地上車上間通信装置、５１…重量センサ、５２…振動センサ、５３…加速度センサ、５４…ジャイロ、５５…ヨーレイトセンサ、２７０～２７３…走行データ、２７４…統計処理、２７５…制御力設定情報２７５，３０１…地上側ＤＢ、３０２…地上側列車走行制御ＤＢ管理装置

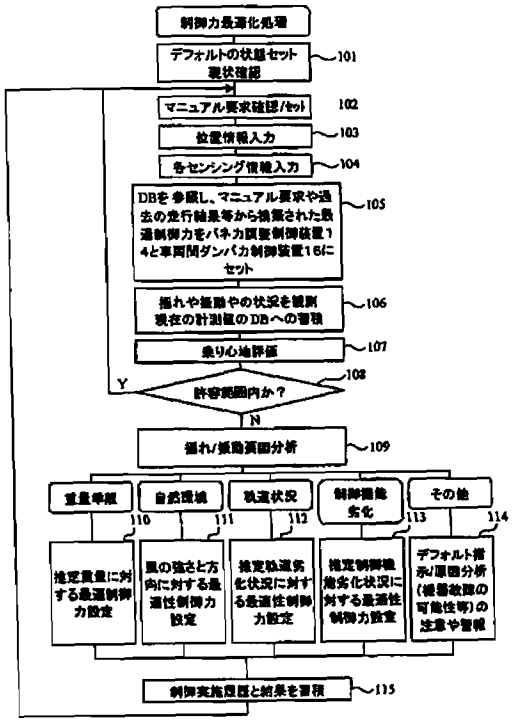
【図１】



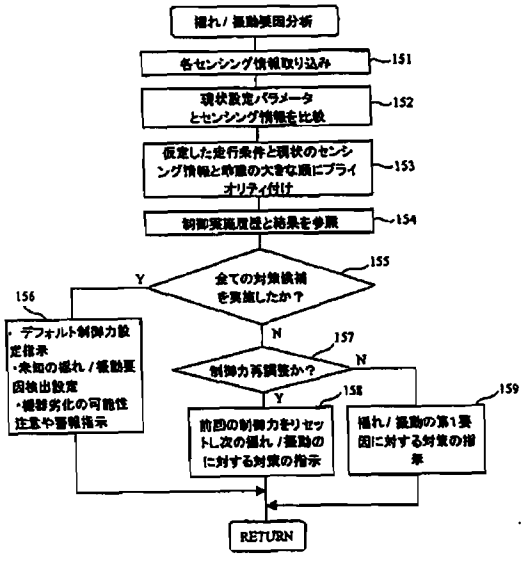
【図２】



【図３】



【図４】

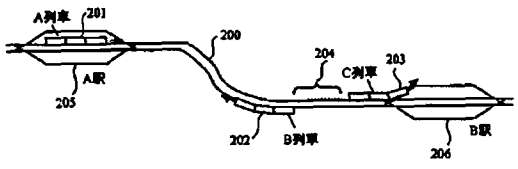


【図５】

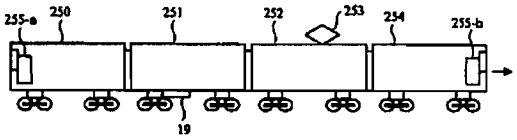
表1

列番X、編成Y	n	n+1	n+2	・・・・・・・・
日時	2002.1.16 17:23:40	2002.1.16 17:23:45	2002.1.16 17:23:50	・・・・・・・・
位置	A線、上り 起点からLn km	A線、上り 起点からLn+1 km	A線、上り 起点からLn+2 km	・・・・・・・・
揺れ/振動量 進行方向: 横方向: 垂直:	振幅,周波数,加速度 wPn,fPn,aPn wRn,fRn,aRn wVn,fVn,aVn	wPn+1,fPn+1,aPn+1 wRn+1,fRn+1,aRn+1 wVn+1,fVn+1,aVn+1	wPn+2,fPn+2,aPn+2 wRn+2,fRn+2,aRn+2 wVn+2,fVn+2,aVn+2	・・・・・・・・
ヨーレート	Yn	Yn+1	Yn+2	・・・・・・・・
振動対策力 全車パネ: 車体ダンパ:	SSn DDn	SSn+1 DDn+1	SSn+2 DDn+2	・・・・・・・・
列車速度	Vn	Vn+1	Vn+2	・・・・・・・・
推定重量	Wn	Wn+1	Wn+2	・・・・・・・・
集合状態 風力/方向: 雨/雪量:	風力/風向 雨量/積雪量 Fn/Wn LRn/LSn	Fn+1/Wn+1 LRn+1/LSn+1	Fn+2/Wn+2 LRn+2/LSn+2	・・・・・・・・

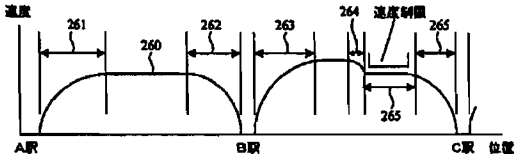
【図６】



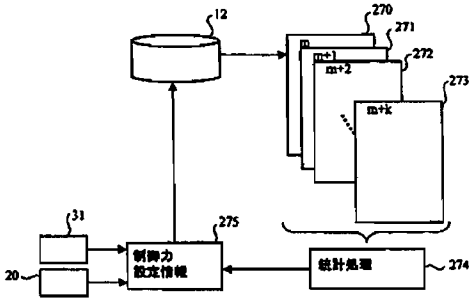
【図７】



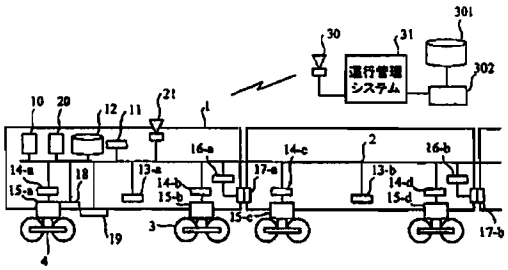
【図８】



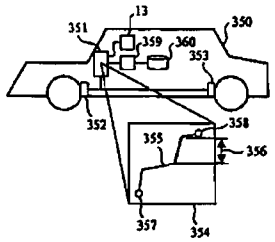
【図９】



【図１０】



【図１１】



フロントページの続き

(72)発明者 佐藤 裕
茨城県日立市大みか町七丁目１番１号 株式会社日立製作所日立研究所内
(72)発明者 関野 貢一
茨城県ひたちなか市市毛１０７０番地 株式会社日立製作所交通システム事業部水戸交通システム本部内

Ｆターム(参考) 3D301 AA09 AA45 AA65 AB21 BA01 DA31 EA86 EB13 EC01
5H115 PA12 PC06 PG04 PI16 PI24 PI29 PO02 PO06 PO09 PO11
PU08 PU11 PU23 PU28 PV09 QA10

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 08-015099

(43)Date of publication of application : 19.01.1996

(51)Int.Cl. G01M 17/08
B61F 5/24
G01H 17/00

(21)Application number : 06-166362

(22)Date of filing : 23.06.1994

(71)Applicant : SUMITOMO METAL IND LTD

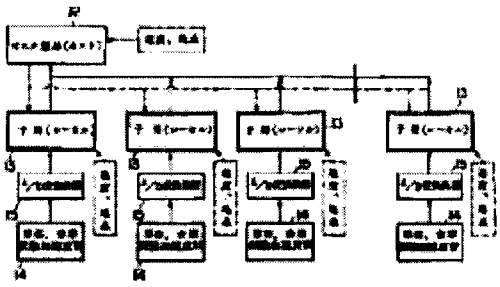
(72)Inventor : NEGORO HISASHI
ISHIKAWA RYUTARO

(54) METHOD FOR MEASURING RIDING COMFORT AND VIBRATION OF RAILWAY VEHICLE

(57)Abstract:

PURPOSE: To provide a method by which the riding comfort of all vehicles constituting a train can be evaluated and the vibration of each vehicle can be displayed and recorded in real time.

CONSTITUTION: A vehicle vibration measuring and processing slave station 13 which inputs the leftward and rightward vibrational acceleration signals and upward and downward vibrational acceleration signals detected by means of vibrational accelerometers 14 to a processor and evaluates the riding comfort levels and vibrations of the vehicles constituting a train is provided at every vehicle or at every several vehicles. A master station 12 which controls all slave stations 13 and receives data-processed indexes converted into the riding comfort levels and vibrations of all vehicles is provided in one vehicle in the train and the riding comfort and vehicle vibrations of the train are evaluated, displayed, and recorded in real time.



(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（A）　(11)特許出願公開番号

特開平8－15099

(43)公開日　平成８年(1996)１月19日

(51)Int.Cl.[6]	識別記号	庁内整理番号	ＦＩ	技術表示箇所
Ｇ０１Ｍ　17/08				
Ｂ６１Ｆ　5/24		Ｚ		
Ｇ０１Ｈ　17/00		Ｚ		
			Ｇ０１Ｍ　17/ 00　Ｆ	

審査請求　未請求　請求項の数３　ＦＤ　（全７頁）

(21)出願番号　特願平6－166362

(22)出願日　平成６年(1994)６月23日

(71)出願人　000002118
住友金属工業株式会社
大阪府大阪市中央区北浜４丁目５番33号

(72)発明者　根来　尚志
大阪府大阪市中央区北浜４丁目５番33号
住友金属工業株式会社内

(72)発明者　石川　龍太郎
大阪府大阪市此花区島屋５丁目１番109号
住友金属工業株式会社製鋼所内

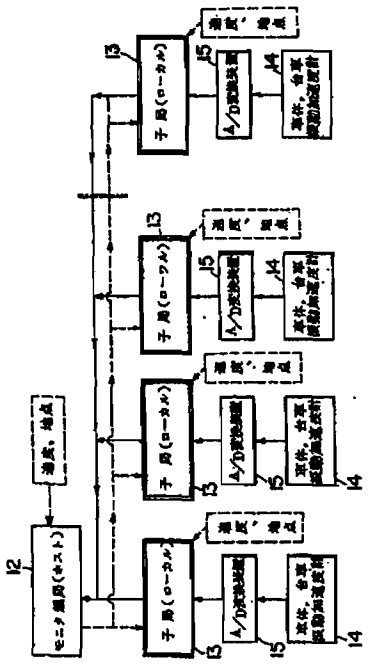
(74)代理人　弁理士　押田　良久

(54)【発明の名称】　鉄道車両の乗り心地と車両振動の測定方法

(57)【要約】

【目的】　編成列車の全車両の乗り心地の評価と車両振動をリアルタイムに表示、記録できる測定方法を提供する。

【構成】　車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度信号を処理装置に入力し、演算処理して乗り心地レベル及び車両振動として評価する車両振動測定処理子局を編成列車の１車両または数車両ごとに設け、前記子局のすべてを統括し、編成全車両の乗り心地レベル及び車両振動に変換されたデータ処理済みの指標を受信する親局を編成中の１車両に設け、編成列車の全車両の乗り心地と車両振動をリアルタイムに評価し表示及び記録する。



1

【特許請求の範囲】

【請求項１】　車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度信号を処理装置に入力し、演算処理して乗り心地レベル及び車両振動として評価する車両振動測定処理子局を編成列車の１車両または数車両ごとに設け、前記子局のすべてを統括し、編成全車両の乗り心地レベル及び車両振動に変換されたデータ処理済みの指標を受信する親局を編成中の１車両に設け、編成列車の全車両の乗り心地と車両振動をリアルタイムに評価し表示及び記録し得ることを特徴とする鉄道車両の乗り心地と車両振動の測定方法。

【請求項２】　親局と子局との間は、親局が順番に子局を呼び出すシリアル通信によることを特徴とする請求項１記載の鉄道車両の乗り心地と車両振動の測定方法。

【請求項３】　一車両に設けた複数個の各種振動加速度計により車体の全モード別の振動加速度を算出し、車体挙動のデータとして記録することを特徴とする請求項１記載の鉄道車両の乗り心地と車両振動の測定方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】この発明は、編成列車の全車両の乗り心地の評価と車両振動をリアルタイムに表示、記録できる測定方法に関する。

【０００２】

【従来の技術】従来、鉄道車両の乗り心地を評価する方法として、例えば該車両の振動加速度を求め、測定した振動と人体の等間隔曲線との比較によるものがある。乗り心地を評価するには、車両の動揺状態を時間的変化を含めて総括的に把握する必要があるが、前記従来方法ではこれらの点が考慮されていなかった。

【０００３】そこで、前記問題点を排除するため、動揺発生頻度測定評価方法において、振動測定手段によって振動測定を行ない、振動測定の測定信号に含まれる周期信号の周期及びその波高値を測定し、周期及びその波高値の一定測定軌間内における発生頻度を求め、振動信号に含まれる周期及びその波高値の発生頻度の分布によって動揺状態の評価を行なう方法（特公平５－６５４号公報）、車両の床面や窓枠上等に置けるポケット型簡易装置により、上下、左右の一定区間の振動ピーク値や限度を超えた回数を係数することにより、乗り心地の状態を簡便に知ることができる車両動揺測定装置（特公平２－７００９号公報）が提案されている。

【０００４】しかし、前記特公平５－６５４号公報及び特公平２－７００９号公報に開示された動揺発生頻度測定評価方法及び動揺測定装置は、車両の乗り心地を該車両の振動頻度から評価するものではあるが、リアルタイムの処理、表示を行なうものではない。また、これらの装置は１車両を対象としたもので、編成列車の全車両を一体に乗り心地や車両振動をリアルタイムに測定するものでもない。

2

【０００５】

【発明が解決しようとする課題】前記のごとく、従来の動揺発生頻度測定評価方法や動揺測定装置は、全て１車両を対象とした乗り心地や振動の測定装置であり、例えば編成列車の先頭車両と後尾車両とでは後尾車両の乗り心地が悪いといわれているが、編成列車の全車両の乗り心地を比較する場合のように、編成列車の全車両の乗り心地や車両振動を測定するには、各車両のすべてに設けた測定装置により個々に得られた結果を一つにまとめて処理するため煩雑な作業が必要であり、系統立てて簡単に比較ができなかった。

【０００６】この発明は、前記の現状に鑑み、編成列車の全車両にわたって一体的に乗り心地や振動の測定が行なえる鉄道車両の乗り心地と車両振動の測定方法を提供するものである。

【０００７】

【課題を解決するための手段】前記目的を達成するため、この発明の鉄道車両の乗り心地と車両振動の測定方法は、車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度信号を処理装置に入力し、演算処理して乗り心地レベル及び車両振動として評価する車両振動測定処理子局を編成列車の１車両または数車両ごとに設け、前記子局のすべてを統括し、編成全車両の乗り心地レベル及び車両振動に変換されたデータ処理済みの指標を受信する親局を編成中の１車両に設け、編成列車の全車両の乗り心地と車両振動をリアルタイムに評価し表示及び記録する。

【０００８】また、前記鉄道車両の乗り心地と車両振動の測定方法において、親局と子局との間は、親局が順番に子局を呼び出すシリアル通信によることを特徴とする。

【０００９】更に、一車両ごとに設けた複数個の各種振動加速度計により車体の全モード別の振動加速度を算出し、車体挙動のデータとして記録することを特徴とする。

【００１０】

【作用】編成列車の全体の乗り心地と振動測定には、各車両の乗り心地と車両振動を車体または台車に設けた振動加速度計により検知した左右振動加速度信号及び上下振動加速度により処理する子局と、各子局が処理した値を表示、記録する親局から構成され、親局と各子局の間は通信で結合することにより、編成列車全体の乗り心地や車両振動を親局でリアルタイムに表示、記録することができる。

【００１１】各子局は、車体に設置した振動加速度計からの検知信号を、次のような処理を行なうことにより車両の乗り心地レベル（ｄＢ）で出力することができる。

【００１２】車体の各振動加速度は、図７の等間隔曲線の逆数の特性を持ったフィルタを用いて重み付けを行な

3

いａｗ（ｔ）とする。そして、得られた乗り心地レベルＬは、下記表１に示す区分により評価する。

【００１３】

【数１】

$$L=10\log\left\{\frac{1}{T}\int_0^T\frac{a^2_w(t)}{a^2_{ref}}dt\right\}$$　　１式

【００１４】ただし、　Ｌ　：　乗り心地レベル（ｄＢ）

ａｒｅｆ　：　基準加速度（いき値）　10^{-5}（ｍ／ｓ^2）

ａｗ（ｔ）　：　重みづけ後の振動加速度　（ｍ／ｓ^2）

Ｔ　：　平均時間

【００１５】

【表１】

区分	乗り心地レベル	評価
①	83dB未満	良↑↓悪
②	83dB以上　88dB未満	
③	88dB以上　93dB未満	
④	93dB以上　98dB未満	
⑤	98dB以上	

【００１６】前記１式では、平均時間Ｔを設定する必要があるため、例えばＴ＝２ｓｅｃもしくは５ｓｅｃとすることで、過去２秒間もしくは過去５秒間の値を求めることができる。これを図８に示すように、振動加速度信号を処理装置に入力し、該処理装置内においてＡ／Ｄ変換装置によりディジタル化した後、前記１式により演算処理して乗り心地レベルＬを求め、出力、記録するが、この際のＡ／Ｄ変換時のサンプリングタイムをΔｔ、例えばΔｔ＝１０ｍｓｅｃとし、Δｔごとに行なうことによりリアルタイムの評価ができる。また、例えば、図９に示すように、その時点で得られた値と過去Ｔ秒間のＴ／Δｔ個のデータとの平均を取って出力、記録してもよい。

【００１７】また、車両振動の測定には、車両振動で一番重要な振幅のピーク値の測定を行なうよう子局において振動加速度計より得られる値から計算、処理する。この振幅のピーク値により各車両の振動の比較ができる。

【００１８】例えば、振動加速度計より得られる値に各周波数ごとのフィルタをかけることで各周波数帯域の振動ピーク値が得られる。図１０（ａ）は得られる振動加速度波形（生波形）に、ローパスフィルタをかけた後の波形を図１０（ｂ）に示す。該図中のＡ（ｎ）は振幅のピーク値で、１／２Ｂ（ｎ）がそのときの振動数となるが、このフィルタ処理を多種類バンドパスフィルタ等、行なうことにより、低周波から高周波にわたって車体の

4

各周波数ごとの振幅のピーク値が得られる。

【００１９】前記の乗り心地、車両振動の計算、処理を各車両の各子局で個々に行ない、得られた結果のみを時々刻々親局に送信する。親局は、各子局から送られてくるデータ（結果）を処理するだけで、全車両にわたっての乗り心地や車両振動を測定できることになる。また、一車両ごとに設けた複数個の各種振動加速度計により車体の全モード別の振動加速度を算出し、車体挙動のデータとして記録することができる。

【００２０】前記のように、編成列車の各車両の車両振動を処理する役割の子局と編成列車の全車両の処理後のデータを受信して表示、記録及び測定する親局に分けることにより、各局の演算負担を軽減すると共に、編成列車の全車両にわたっての乗り心地と振動測定を同時にリアルタイムで処理することができる。

【００２１】

【実施例】この発明の実施例を図面に基づいて説明する。図１に示すように、車体前後振動加速度計ａと、車体左右振動加速度計ｂ、ｃと、車体上下振動加速度計ｄ、ｅ、ｆ、ｇの７個の振動加速度計を、車両の全自由度（６自由度）の振動モードを計算できるように車体１０の床面に設置する。更に、前後の台車１１に左右振動加速度計及び上下振動加速度計ｈ、ｉ、ｊ、ｋを設ける台車振動を測定できるようにしてよい。そして、下記の計算により車体の振動モードを抽出する。

【００２２】車体前後モード　＝　ａ

車体左右モード　＝　（ｂ＋ｃ）／２

車体ヨーモード　＝　（ｂ－ｃ）／２

車体上下モード　＝　（ｄ＋ｅ＋ｆ＋ｇ）／４

車体ロールモード　＝　（ｄ－ｅ＋ｆ－ｇ）／４

車体ピッチモード　＝　（ｄ＋ｅ－ｆ－ｇ）／４

【００２３】また、乗り心地の計算では、左右については、車体左右振動加速度計ｂ、ｃを用い、上下については、車体上下振動加速度計ｄまたはｅ、もしくは（ｄ＋ｅ）／２と、ｆまたはｇ、もしくは（ｆ＋ｇ）／２を用いる、前後についてはａを用いる。これにより一両の前位側と後位側の上下、左右の乗り心地と前後の乗り心地を得ることができる。また、前記のごとく車体の６自由度を計算しないのであれば、図２に示すように車体１０の床面の台車中心上に車体左右振動加速度計ｂ、ｃと、その位置に車体前後振動加速度計ａと車体上下振動加速度計ｄ、ｆを設置したものでもよい。これにより、一両の前位側と後位側の上下、左右、前後の乗り心地を得ることができる。

【００２４】前記図１に示す振動加速度計の配置を、図３に示すように９両編成の列車の全車両の１両目～９両目に設置し、各振動加速度計からの検知信号を処理する子局１３を各車両に設ける。なお、１両目車両用の子局１３は２両目車両に搭載した。そして、各車両の各子局１３で処理された処理後のデータを受信して表示、記録

5

及び測定する親局１２を２両目車両に搭載した。子局１３と親局１２の間はシリアル通信線により接続した。なお、子局１３は例えば前後車両の２車両ごとに１子局を設けるなど数車両ごとに設けてもよい。

【００２５】前記編成列車における乗り心地と車両振動の測定装置の機器構成を図４に示す。各車両（１両目～９両目）は、それぞれ各振動加速度計１４で検知した検知信号はＡ／Ｄ変換装置１５に通してディジタル化して各子局１３に入力する。各子局１３では後記の処理を行ない得られたデータ（結果）を親局１２に送信する。そして、親局１２はそのデータ（結果）をモニタ表示し記録する。また、測定が行なわれる。この際、測定点を明らかにするため、車両速度や地点情報入力ができるように構成される。なお、各子局１３においても同様に車両速度や地点情報入力ができるようにする。また、ディジタル化されたＡ／Ｄ変検後の各振動加速度計の信号も子局に記録される。

【００２６】前記実施例装置における乗り心地の計算は、前述した方法により行なわれ、乗り心地レベル（ｄＢ）として出力される。この結果はデータとして親局１２に送信すると同時に子局１３でも記録しておき、後のデータ処理に役立てる。この際の処理の流れを図５のブロック図に示す。各振動加速度計で検知した検知信号はＡ／Ｄ変換装置に通してディジタル化し図７の等間隔曲線の逆数の特性を持ったフィルタを用いて重み付けした後、前記１式により計算する。この方法により、サンプリングタイムΔｔごとに過去２秒間または過去５秒間の乗り心地が左右、上下及び前後について得られる。

【００２７】車体振動については、生データを親局に送信するのではなく、車体振動の最大値が問題となることが多いので、前記の方法により各振動モードごとに図６に示すような周波数帯域にフィルタにより分け、過去２秒間のその周波数帯域での最大値を子局により演算する。なお、各周波数帯域の分け方は更に細分化してもよい。また、台車振動も前記と同様な方法でフィルタ後の値から最大値を出力演算結果を親局に送信する。更に、車体振動も各モードに分けずに、各振動加速度計の最大値を出力するようにしてもよい。

【００２８】前記のようにして得られた各子局のデータ（結果）を親局は受信する。またこのときの車両速度や地点情報も入力する。この発明の方法によれば、親局では各車両の同時点でのデータが得られるので、後のデータ処理や各車両の乗り心地、車両振動の比較が簡単にできる。

6

【００２９】

【発明の効果】この発明によれば、編成列車の各車両の車両振動を処理する役割の子局と編成列車の全車両の処理後のデータを受信して表示、記録及び測定する親局に分けることにより、各局の演算負担を軽減すると共に、編成列車の全車両にわたっての乗り心地と振動測定を同時にリアルタイムで処理することができる。

【図面の簡単な説明】

【図１】この発明の実施例における、車体床面及び台車に配置した各種振動加速度計の説明図である。

【図２】この発明の実施例において、車体床面の進行方向中央の前後に各種振動加速度計を設置した場合の説明図である。

【図３】この発明を実施するための装置を有する編成列車の一例を示す説明図である。

【図４】この発明の実施例における振動加速度の処理の流れを示すブロック図である。

【図５】この発明の実施により乗り心地をリアルタイムに評価するためのΔｔ時間ごとに行なう処理の流れを示すブロック図である。

【図６】この発明の実施により各振動モードごとの周波数帯域での最大値をリアルタイムに評価するためのΔｔ時間ごとに行なう処理の流れを示すブロック図である。

【図７】等間隔曲線を示すグラフである。

【図８】この発明の実施により乗り心地をリアルタイムに評価するためのΔｔ時間ごとに行なう処理の流れを示すブロック図である。

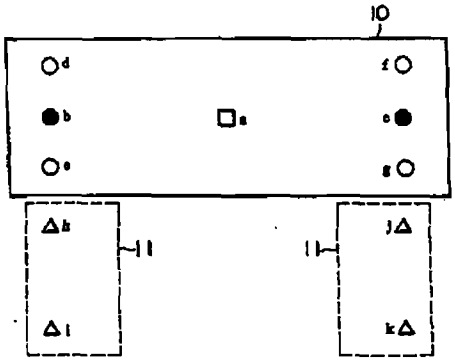
【図９】その時点で得られた値と過去Ｔ秒間のＴ／Δｔ個のデータとの平均の関係を示す説明図である。

【図１０】図１０（ａ）は車体または台車の上下または左右の振動加速度波形を示すグラフ、図１０（ｂ）はローパスフィルタを通した後の振動加速度波形を示すグラフである。

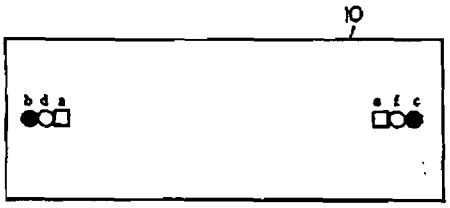
【符号の説明】

１～９　車両ＮＯ.
１０　車両
１２　親局
１３　子局
１４　振動加速度計
１５　Ａ／Ｄ変換装置
ａ　車体前後振動加速度計
ｂ、ｃ　車体左右振動加速度計
ｄ、ｅ、ｆ、ｇ　車体上下振動加速度計
ｈ、ｉ、ｊ、ｋ　台車左右、上下振動加速度計

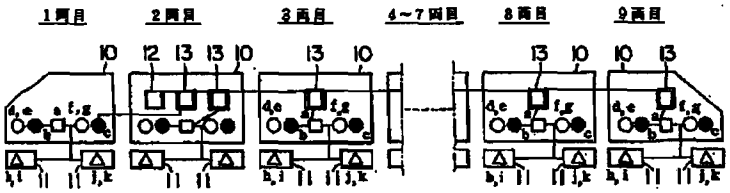
【図1】



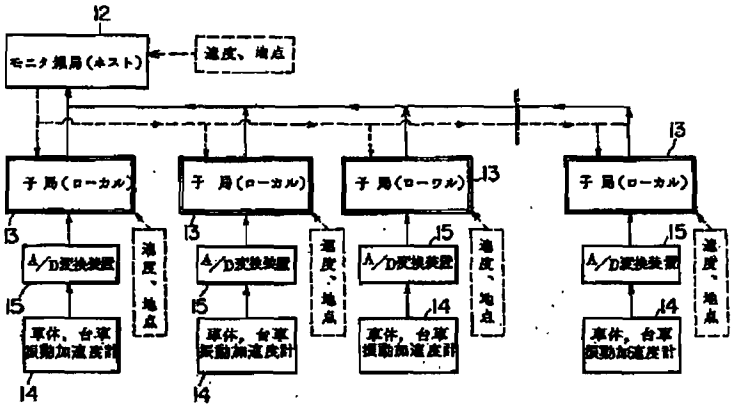
【図2】



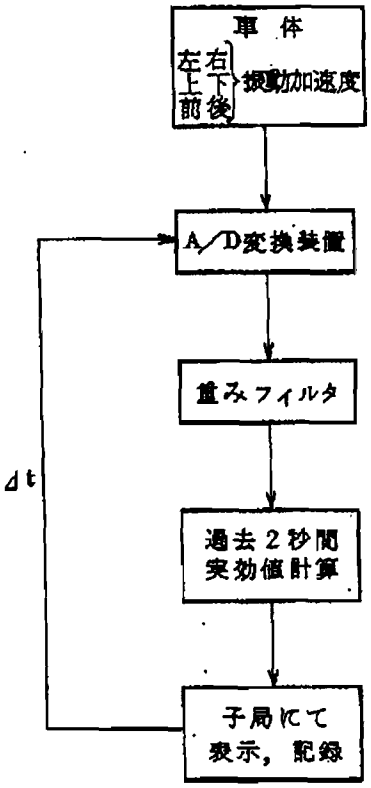
【図3】



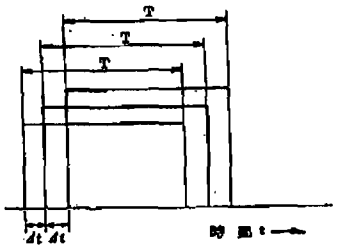
【図4】



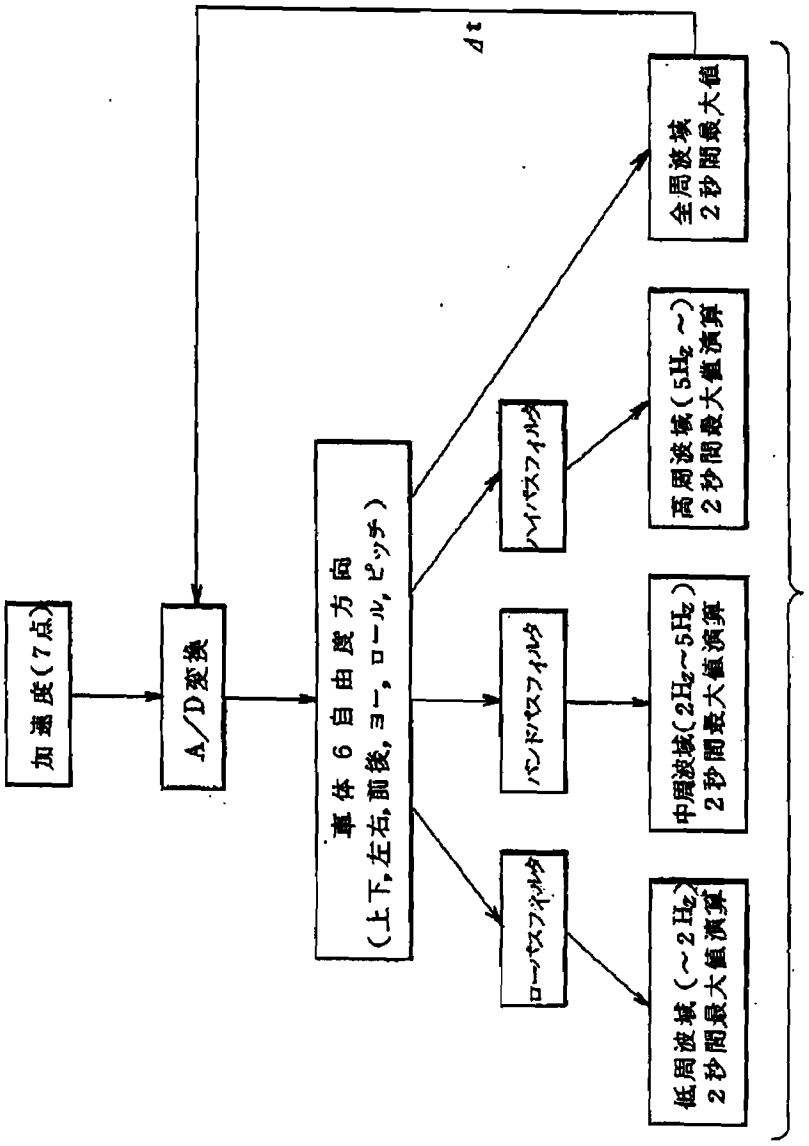
【図5】



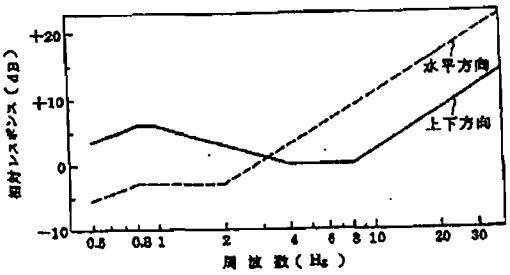
【図9】



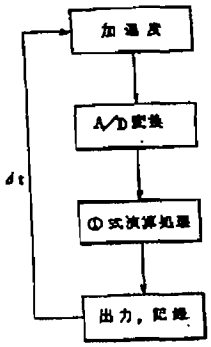
【図6】


加速度(7点)
A/D変換
車体6自由度方向
(上下,左右,前後,ヨー,ロール,ピッチ)
Δt
ローパスフィルタ
バンドパスフィルタ
ハイパスフィルタ
低周波域(～2Hz)
2秒間最大値演算
中周波域(2Hz～5Hz)
2秒間最大値演算
高周波域(5Hz～)
2秒間最大値演算
全周波域
2秒間最大値

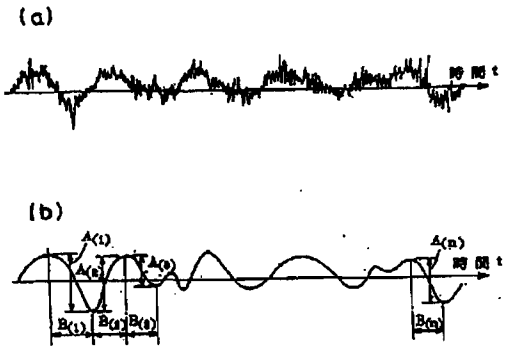
【図７】


+20
+10
0
−10
0.5
0.8 1
2
4
6
8 10
20
30
水平方向
上下方向
周 波 数（Hz）

【図８】


加 速 度
A/D 変換
Δt
① 式演算処理
出力，記録

【図１０】


(a)
時 間 t
(b)
A(1)
A(2)
A(3)
A(n)
時 間 t
B(1)
B(2)
B(3)
B(n)

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 10-217968

(43)Date of publication of application : 18.08.1998

(51)Int.Cl. B61L 25/04
B61L 25/02

(21)Application number : 09-026527

(22)Date of filing : 10.02.1997

(71)Applicant : TOSHIBA CORP

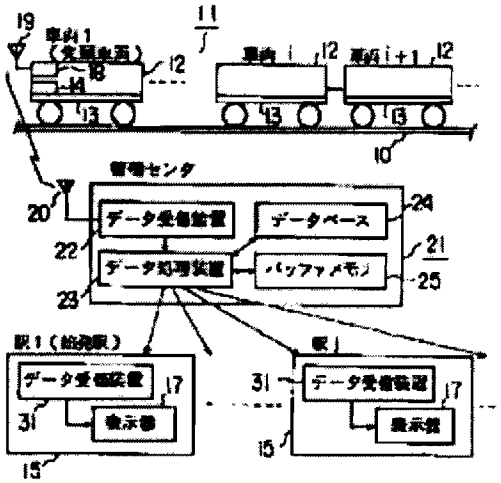
(72)Inventor : UNE YASUSHI

(54) TRAIN CONGESTION DEGREE INDICATION METHOD AND ITS INDICATION SYSTEM

(57)Abstract:

PROBLEM TO BE SOLVED: To provide more accurate information on the degree of congestion for each rolling stone of a train arriving at for passengers waiting for the net train on the platform of a station.

SOLUTION: The weight of passenger per rolling stone is continuously measured for the measuring period of time T from time when a train 11 arrives at each station 15 until time when the train leaves the station, the number of passengers except those having left the train Naij corresponding to the minimum weight which is continuously measured during the measuring period of time per rolling stock, and the number of passengers all aboard Nbij corresponding to the weight at the time when measuring has been over, are obtained first. The estimated number of passengers leaving the train Bij+1 at the nest station, which can be obtained based on the actual number of passengers leaving a train in the past, is subtracted from the number of passengers all aboard obtained as mentioned above for the present station, the number of remaining passengers Cij+1 per rolling stock at the next station is thereby computed, the number of remaining passengers per rolling socke is made a congestion condition Dij+1 per rolling stock, and it is outputted so as to be indicated for an indication device 17 at the next station.



(19)日本国特許庁（ＪＰ）　(12)公開特許公報（Ａ）　(11)特許出願公開番号
特開平10－217968
(43)公開日　平成10年(1998)８月18日

(51)Int.Cl.[6]	識別記号	ＦＩ		
Ｂ６１Ｌ　25/04		Ｂ６１Ｌ　25/04		
25/02		25/02		Ａ

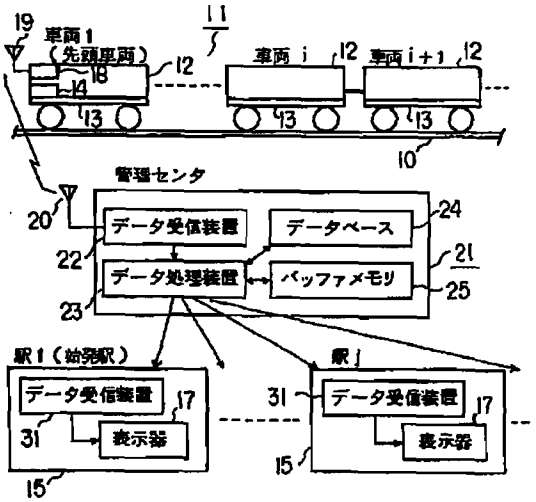
審査請求　未請求　請求項の数２　ＯＬ　（全８頁）

(21)出願番号　特願平9－26527
(22)出願日　平成９年(1997)２月10日

(71)出願人　000003078
株式会社東芝
神奈川県川崎市幸区堀川町72番地
(72)発明者　宇根　靖
東京都府中市東芝町１番地　株式会社東芝府中工場内
(74)代理人　弁理士　鈴江　武彦　（外６名）

(54)【発明の名称】　列車混雑度表示方法及びその表示システム

(57)【要約】
【課題】　駅１５のホーム１６で次の列車１１を待っている乗客に対して到着列車の各車両１２のより正確な混雑状況の情報を提供する。
【解決手段】　列車１１が各駅１５に到着してから該当駅を出発するまでの計測期間Ｔにおける各車両毎の乗客重量を連続測定し、この連続測定された各車両の計測期間における最小重量に対応する降車後乗客数N_{aij}と計測期終了時の重量に対応する乗車後乗客数N_{bij}とを求め、この求められた現在駅の乗車後乗客数から、過去の実績降車客数にて得られる次駅の予測降車客数B_{ij+1}を減算して、次駅における各車両の残留乗客数C_{ij+1}を算出し、この算出された各車両の残留乗客数を各車両の混雑状況D_{ij+1}として次駅の表示装置１７に表示出力する。



1

【特許請求の範囲】

【請求項１】　列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定し、

この連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求め、

この求められた現在駅の乗車後乗客数から、過去の実績降車客数にて得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出し、

この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力することを特徴とする列車混雑度表示方法。

【請求項２】　列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定する乗客重量測定装置と、

この乗客重量測定装置にて連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求める乗客数抽出手段と、

列車が任意駅の一つ前の駅に到着した時に前記乗客数抽出手段で得られる前駅の乗車後乗客数から任意駅に到着した時に前記乗客数抽出手段で得られる任意駅の降車後乗客人数を減算して任意駅における各車両の実績降車客数を算出する実績降車客数算出手段と、

各駅毎に算出される各車両の実績降車客数を記憶する実績降車客数メモリと、

前記乗客数抽出手段で求められた現在駅の乗車後乗客数から、前記実績降車客数メモリに記憶された次駅の実績降車客数から得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出する残留乗客数算出手段と、

この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力する表示制御手段とを備えた列車混雑度表示システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、鉄道機関において、各駅のホームで列車を待つ乗客に対して次に到着する列車の混雑状況を表示装置に表示する列車混雑度表示方法及びこの方法を採用した列車混雑度表示システムに関する。

【０００２】

【従来の技術】都市近郊の通勤列車等においては、例えば、列車がホームに停車した場合におけるホームの出口近傍や入口近傍に停車する車両には多くの乗客が乗車して乗車率が高くなり、ホームの中間に位置する車両は少ない乗客しか乗車しない。

【０００３】その結果、列車の一部の車両の混雑度のみが高くなり、鉄道会社にとって、乗客の輸送効率が低下

2

するのみならず、乗客にとっても不快な通勤を強いられることになる。

【０００４】このような不都合を解消するために、次に到着する列車における各車両の混雑度（乗車率）を測定して例えばホームや改札口の上方位置に取付けられた電光表示器に各車両毎の混雑度（乗車率）を表示して、乗客に混んだ車両を避けて空いた車両に乗車するように注意を促す案が提唱されている（特開平２－１３３２７８号公報）。

【０００５】すなわち、図８（ａ）に示すように、複数の車両２からなる列車１が駅のホームに停車する場合、ホームにおける各車両２の停止位置は予め定められているので、レール３における各車両２の停止位置に荷重検出器４を取付け、この各荷検出器４で得られた車両の重量を測定する。そして、演算制御器５で各車両２の乗車客数を算出して、さらに、この乗車客数を車両の定員で除算して各車両毎の乗車率（混雑度）を算出する。そして、算出された各車両毎の乗車率（混雑度）を次駅へ送信する。

【０００６】次駅では、一つ前の駅から受信した次にホームに到着する列車の各車両の乗車率（混雑度）を図８（ｂ）に示すように、ホームや改札口の上方位置の電光表示器７に表示する。

【０００７】したがって、ホームの乗客又は改札口からホームに入る乗客は次にホームに到着する列車においてどの車両が混んでいるかを即座に判断でき、空いた車両が停車する位置へ移動することが可能である。

【０００８】

【発明が解決しようとする課題】しかしながら図８に示す列車の各車両の混雑度の表示手法においても、まだ改良すべき次のような課題があった。すなわち、乗換え駅や大きな駅においては、列車の降車客が多くて、この駅を通過する列車においては、この駅を発車する時点で各車両の乗客が大幅に減少して、ホームで該当列車に乗車する客に対して、乗車車両の変更を促す図８（ｂ）に示す各車両毎の乗車率（混雑度）を表示することが無意味になる場合もある。一方、客にとっては、特にホームを移動する必要がないのに、移動を結果的に強制されることになり、乗客に対するサービスが逆効果となる懸念がある。

【０００９】その結果、一つの列車における各車両相互間の乗車率の偏在がさらに拡大して、乗客の降り乗りに要する時間が増加し、鉄道運送業務全体の輸送効率が低下する懸念がある。

【００１０】また、例えば乗換え駅における他の線路に対する乗換え通路がホームのある特定位置に存在する場合は、この乗換え通路近傍に停止する車両の乗車率（混雑度）が極端に高いが、該当駅でこの車両のほとんどの乗客が降車して、この駅を発車する時点においては、該当車両の乗車率（混雑度）が極端に低下する場合もあ

3

る。

【００１１】このような場合においては、ホームの乗客はこの空いた車両に乗車することが好ましい。しかし、表示案内には該当車両の乗車率（混雑度）が極端に高いと表示される。したかって、結果的にホームの乗客を誤った位置へ導く懸念がある。

【００１２】本発明はこのような事情に鑑みてなされたものであり、各車両の乗客重量を連続測定することによって、次駅における各車両から乗客が降りた後の残留乗客数を予測でき、この残留乗客数を混雑状況として表示でき、駅のホームにいる列車待ちの客に対してより有用な情報を提供でき、かつ１列車内における各車両相互間の乗車率を均一化でき、全体としての輸送効率を向上できる列車混雑度表示方法及び列車混雑度表示システムを提供することを目的とする。

【００１３】

【課題を解決するための手段】上記課題を解消するために本発明の列車混雑度表示方法においては、列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定し、この連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求め、この求められた現在駅の乗車後乗客数から、過去の実績降車客数にて得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出し、この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力するようにしている。

【００１４】また、本発明の列車混雑度表示システムにおいては、列車が各駅に到着してから該当駅を出発するまでの計測期間における各車両毎の乗客重量を連続測定する乗客重量測定装置と、乗客重量測定装置にて連続測定された各車両の計測期間における最小重量に対応する降車後乗客数と計測期終了時の重量に対応する乗車後乗客数とを求める乗客数抽出手段と、列車が任意駅の一つ前の駅に到着した時に乗客数抽出手段で得られる前駅の乗車後乗客数から任意駅に到着した時に乗客数抽出手段で得られる任意駅の降車後乗客人数を減算して任意駅における各車両の実績降車客数を算出する実績降車客数算出手段と、各駅毎に算出される各車両の実績降車客数を記憶する実績降車客数メモリと、乗客数抽出手段で求められた現在駅の乗車後乗客数から、実績降車客数メモリに記憶された次駅の実績降車客数から得られる次駅の予測降車客数を減算して、次駅における各車両の残留乗客数を算出する残留乗客数算出手段と、この算出された各車両の残留乗客数を各車両の混雑状況として次駅の表示装置に表示出力する表示制御手段とを備えている。

【００１５】このように構成された列車混雑度表示方法及びその表示システムの各駅における到着列車の混雑度の算出原理を説明する。列車が一つの駅に到着して車両の扉が開くと当駅で下車する乗客が車両から降りるので、該当車両の乗客重量は一旦低下する。そして、当駅で下車する乗客が全て降車すると、次に当駅から乗車する客が該当車両に乗車するので、乗客重量は上昇する。そして、扉が閉じて列車が当駅を発車する時点においては、乗客重量は一定になる。

4

【００１６】列車が駅に到着してから該当駅を出発するまでの計測期間における最小重量から降車後乗客数を求め、計測期終了時の重量から乗車後乗客数を求めることができる。よって、一つ前の駅の乗車後乗客数から当駅の降車後乗客数を減算することによって、当駅の各車両の降車乗客数を算出できる。このように、各駅における各車両の降車乗客数を過去の実績データとして蓄積することが可能である。

【００１７】そして、現在駅で得られた各車両における乗車後乗客数から次駅の予測降車客数を減算して、次駅における各車両の残留乗客数が予測できる。この残留乗客数が次駅において、乗客が各車両から降りた時点における実際の混雑度となる。

【００１８】したがって、たとえ現在駅で特定車両の乗車率（混雑度）が高かったとしても、次の駅で該当車両からの降車乗客数が多いと過去の実績に基づいて予想される場合は、次駅において該当車両の混雑度は低いと表示される。逆に、予測降車乗客数が少ない場合は、表示される混雑度は高いまま維持される。このように、ホームで列車を待つ乗客にとって、自己がこれから乗車しようとする車両の正しい乗車率（混雑度）を確認できる。

【００１９】

【発明の実施の形態】以下本発明の一実施形態を図面を用いて説明する。図１は実施形態の列車混雑度表示方法が採用された列車混雑度表示システムの概略構成を示す模式図である。

【００２０】鉄道線路のレール１０上を走行する列車１１は例えば１０両を越える複数の車両１２で編成されている。なお、各車両１２には先頭から順番に車両番号ｉ（ｉ＝１，２，３，４，…）が付されている。そして、各車両１２の床下には、該当車両１２の重量を計測する重量計１３が設置されている。乗客が全く乗っていない状態の車両重量は予め測定されており、重量計１３は測定重量から車両重量を減算した乗客のみの乗客重量Wi（i=1,2,3,4.…）を出力する。各車両１２の各重量計１３から出力される各車両１２の乗客重量Wi（i=1,2,3,4.…）は先頭の車両１２の送信データ作成部１４へ伝送される。

【００２１】受信データ作成部１４は各重量計１３から乗客重量Wi を受領すると、各乗客重量Wi に対して所定のデータ処理を行って、データ処理結果をデータ送信装置１８へ送出する。データ送信装置１８は受信データ作成部１４から受領したデータ処理結果をアンテナ１９から電波出力する。

【００２２】各列車１１から電波出力されたデータ処理

5

結果は鉄道線路に沿って敷設されたアンテナ２０を介して例えば鉄道会社の本社に設置された管理センタ２１のデータ受信装置２２で受信される。データ受信装置２２は各列車１１から受信したデータ処理結果をデータ処理装置２３へ送出する。データ処理装置２３はデータ処理結果をデータベース２４及びバッファメモリ２５の記憶内容を用いてデータ処理を実施する。

【００２３】一方、鉄道線路に沿って始発駅から終着駅までの複数の駅１５が配設されている。各駅１５には、列車１１の走行方向に沿って始発駅から終着駅慶で順番に駅番号ｊ（ｊ＝１，２，３，４，…）が付されている。そして、図２に示すように、各駅１５のホーム１６の各ホーム入口の上方位置には電光表示板で構成された表示器１７が取付けられている。

【００２４】各表示器１７には、図３で示すように、列車の各進行方向に対応する２種類の列車パターン２６，２７が表示される。各列車パターン２６，２７は先頭車両から末尾車両までの複数の車両パターン２６ａ，２７ｂで構成されている。そして、各車両パターン２６ａ，２６ｂはそれぞれ次にこのホーム１６に到着する列車１１の各車両１２の混雑度に応じた色で表示される。例えば［緑色］は混雑でない通常状態を示し、［黄色］は混雑を示し、［赤色］は大混雑を示す。

【００２５】次に、各部における詳細動作を順番に説明する。図４は、列車１１が駅１５のホーム１６に到着してから該当駅１５を発車するまでの期間（計測期間Ｔ）における各車両１２の乗客重量W_i（i=1,2,3,4.…）の変化を示す図である。列車１１が駅１５のホーム１６に到着して扉が開くと、乗客が降車するので乗客重量W_iは低下し、全ての降車客が降りた時点で、乗客重量W_iは最小値を示す。この最小値を該当駅１５（駅番号ｊ）における該当車両１２（車両番号ｉ）の降車後乗客重量W_{aij}と定義する。また、全ての降車客が降りた後に、該当駅１５のホーム１６で待っていた客がこの車両１２に乗込むと乗客重量W_iが上昇する。そして、全ての客が乗車して、扉が閉じて、列車１１が該当駅１５（駅番号ｊ）を発車した時点における乗客重量W_iを乗車後乗客重量W_{bij}と定義する。

【００２６】したがって、一つ前の駅１５（駅番号ｊ－１）の乗車後乗客重量W_{bij-1}が既知の場合、該当駅１５（駅番号ｊ）で降車した降車乗客重量W_{cij}が演算により求まる。

【００２７】各車両１２の各重量計１３は速度計等から列車１１の停止期間に対応する計測期間Ｔを検出して、この計測期間Ｔにおける乗客重量W_iを連続して計測して、送信データ作成部１４へ送出する。

【００２８】各列車１１の送信データ作成部１４は自己の列車１１の走行位置を常時監視しており、該当列車１１が駅１５のホーム１６に到着すると該当駅１５の駅番号ｊを把握できる。

6

【００２９】そして、送信データ作成部１４は図６に示す流れ図に従ってデータ処理を実行する。Ｓ（ステップ）１において、該当列車１１がｊ番目の駅１５のホーム１６に到着すると、各車両１２の各重量計１３から計測期間Ｔにおける連続した乗客重量W_{ij}（i=1,2,3,4,…）を受信する（Ｓ２）。次に、各連続乗客重量W_{ij}から各車両１２における降車後乗客重量W_{aij}（i=1,2,3,4,…）を検出し（Ｓ３）、さらに、乗車後乗客重量W_{bij}（i=1,2,3,4,…）を検出する（Ｓ４）。そして、自己の列車１１を特定する列車番号と検出した降車後乗客重量W_{aij}（i=1,2,3,4,…）と乗車後乗客重量W_{bij}（i=1,2,3,4,…）とをデータ送信装置１８を介して、管理センタ２１へ送信する（Ｓ５）。

【００３０】管理センタ２１のデータ受信装置２２は各列車１１から受信した列車番号と降車後乗客重量W_{aij}と乗車後乗客重量W_{bij}とをデータ処理装置２３へ送付する。

【００３１】デー処理装置２３のデータベース２４には、図５に示すように実績降車客数メモリ２８、実績乗車客数メモリ２９及び列車運行情報メモリ３０が形成されている。

【００３２】実績降車客数メモリ２８内には、各駅１５（駅番号ｊ＝１，２，３，４，…）における各車両１２（車両番号ｉ＝１，２，３，４，…）の過去の実績の降車客数が記憶されている。同様に、実績乗車客数メモリ２９内には、各駅１５における各車両１２の過去の実績の乗車客数が記憶されている。また、列車運行情報メモリ３０内には、各列車番号毎に、該当列車１１の各駅１５における到着ホーム（停車番線）、到着時刻、発車時刻等の列車運行に関する運行ダイヤが記憶されている。

【００３３】バッファメモリ２５内には、各列車１１から受領した現在駅１５（駅番号ｊ）及び一つ前の駅１５（駅番号ｊ－１）における降車後乗客重量W_{aij}，W_{aij-1}と乗車後乗客重量W_{bij}，W_{bij-1}とを記憶保持する。

【００３４】そして、データ処理装置２３は図７の流れ図に従ってデータ処理を実行する。先ず、Ｑ１にて、データ処理部２３は一つの列車１１からｊ番目の駅１５を発車した直後に該当駅１５における列車番号と降車後乗客重量W_{aij}と乗車後乗客重量W_{bij}とを受信すると、データベース２４の列車運行情報メモリ３０を検索して（Ｑ２）、該当列車１１の次駅１５（駅番号ｊ＋１）及び次駅１５における停車番線（停車ホーム）を決定する（Ｑ３）。

【００３５】次に、乗客一人当りの平均重量は例えば６０Ｋｇ等の予め統計的に求まっているので、降車後乗客重量W_{aij}と乗車後乗客重量W_{bij}とからｊ番目の駅１５における降車後乗客数N_{aij}（i=1,2,3,4,…）と乗車後乗客数N_{bij}（i=1,2,3,4,…）を算出する（Ｑ４）。この求めた降車後乗客数N_{aij}と乗車後乗客数N_{bij}と

7

をバッファメモリ２５に記憶保持しておく（Ｑ５）。

【００３６】次に、データベース２４の実績降車客数メモリ２８から次駅１５（駅番号ｊ＋１）における各車両１２（車両番号i=1,2,3,4,…）の実績降車客数E_{ij+1}を読出して（Ｑ６）、この読出した実績降車客数E_{ij+1}を次駅１５（駅番号ｊ＋１）での予測降車客数B_{ij+1}（i=1,2,3,4,…）とする（Ｑ７）。そして、この予測降車客数B_{ij+1}を用いて次駅１５（駅番号ｊ＋１）における該当列車１１における各車両１２の予測残留乗客数C_{ij+1}（i=1,2,3,4,…）を下式を用いて算出する（Ｑ８）。

【００３７】$C_{ij+1}=N_{bij}-B_{ij+1}$　　i=1,2,3,4,…

次駅１５（駅番号ｊ＋１）における予測残留乗客数C_{ij+1}が求まると、この予測残留乗客数C_{ij+1}を各車両１２の定員で除算して、次駅１５（駅番号ｊ＋１）における各車両１２（i=1,2,3,4,…）における乗客の乗車前の混雑度（乗車率%）D_{ij+1}（i=1,2,3,4,…）を算出する（Ｑ９）。

【００３８】$D_{ij+1}=C_{ij+1}\div$定員$\times 100$　　(%)

算出した各車両１２の乗車前の混雑度D_{ij+1}（i=1,2,3,4,…）を次駅１５（駅番号ｊ＋１）へ列車番号と共に送信する（Ｑ１０）。

【００３９】次に、現在駅１５（駅番号ｊ）における各車両１２の実績降車客数E_{ij}（i=1,2,3,4,…）をバッファメモリ２５に保存されている一つ前の駅１５（駅番号ｊ－１）における乗車後乗客数N_{bij-1}と現在駅１５（駅番号ｊ）の降車後乗客数N_{aij}を用いて下式で算出する（Ｑ１１）。

【００４０】

$E_{ij}=N_{bij-1}-N_{aij}$　　i=1,2,3,4,…

そして、Ｑ１２にて、この算出された実績降車客数E_{ij}に対して補正を加える。すなわち、車両１２が混雑している場合は、列車１１がホーム１６に到着して各車両１２の扉が開くと、扉近傍の客が自己がこの駅１５で下車しない場合においても、一旦ホーム１６へ降車し、降車客が全て降車したのち再度同一車両１２へ乗車する。このような場合、測定された降車後乗客数N_{aij}が実際より少なくなる。その結果、算出された実績降車客数E_{ij}が実際より多くなる。この一旦ホーム１６へ降車する乗客数は、前駅１５における発車後の各車両１２の混み程度を示す乗車後乗客数N_{bij-1}に応じて、経験的にほぼ一定値に定まるので、算出された実績降車客数E_{ij}からこの乗客数を減算する。

【００４１】そして、補正された後の実績降車客数E_{ij}（i=1,2,3,4,…）をデータベース２４の実績降車客数メモリ２８へ登録する（Ｑ１３）。具体的には、実績降車客数メモリ２８の対応する平均的な客数を該当実績降車客数E_{ij}で学習して、さらに正確な値に更新する。

【００４２】次に、現在駅１５（駅番号ｊ）における各車両１２の実績乗車客数F_{ij}（i=1,2,3,4,…）をバッファメモリ２５に保存されている降車後乗客数N_{aij}と乗車後乗客数N_{bij}とを用いて算出する（Ｑ１４）。

8

【００４３】

$F_{ij}=N_{bij}-N_{aij}$　　i=1,2,3,4,…

この求めた実績乗車客数F_{ij}をデータベース２４の実績乗車客数メモリ２９へ登録する（Ｑ１５）。

【００４４】なお、この実績乗車客数メモリ２９に登録された各駅１５，各車両１２の実績乗車客数F_{ij}は後日該当鉄道会社における列車ダイヤ編成や駅舎建設の参考データに使用される。

【００４５】以上で、一つの列車１１が一つの駅１５（駅番号ｊ）を発車した時における次駅１５（駅番号ｊ＋１）での各車両１２の乗車前の混雑度D_{ij+1}の算出処理が終了したので、駅番号ｊを更新して（Ｑ１６）、Ｑ１へ戻り、次の駅１５からのデータ受信を待つ。

【００４６】管理センタ２１のデータ処理装置２３から列車番号と各車両１２の乗車前の混雑度D_{ij+1}（i=1,2,3,4,…）を受信した次の駅１５（駅番号ｊ＋１）のデータ受信装置３１は、乗車前の混雑度D_{ij+1}（i=1,2,3,4,…）を該当列車１１が到着するホーム１６の表示器１７に図３に示すように各車両１２の各車両パターン２６ａ，２７ｂ毎に色別表示する。

【００４７】例えば［緑色］は混雑でない通常状態を示し、［黄色］は混雑を示し、［赤色］は大混雑を示す。この各車両パターン２６ａ，２７ｂを［緑色］，［黄色］，［赤色］に色別表示する場合における混雑度D_{ij+1}の各境界値（表示範囲）は各鉄道会社が過去の実績に基づいて決定する。

【００４８】このように構成された列車混雑度表示方法が採用された列車混雑度表示システムにおいては、各駅１５のホーム１６の上方位置の表示器１７に表示される次にこのホーム１７に到着する列車１１の各車両１２の混雑度D_{ij}は一つ前の駅１５で測定された乗車後乗客重量W_{bij-1}から得られた乗車後乗客数N_{bij-1}から当駅１５で該当車両１２から降車する予測降車客数B_{ij}を減算した当駅での予測残留乗客数C_{ij}から求めている。

【００４９】したがって、ホーム１６で列車１１の到着を待っている乗客にとっては、ホーム１６に到着してまだ当駅１５で降車予定の乗客が乗車した状態の混雑度ではなくて、当駅１５で降車客が各車両１２から降車した後の混雑度D_{ij}が表示される。したがって、これから、乗車しようとする車両１２の正確な混雑度が把握でき、当駅１５を発車する列車１１の各車両１２相互間の混雑度がより一層均一化できる。

【００５０】その結果、乗客にとって不快な通勤を少しでも回避でき、鉄道会社にとっても、各列車１１における乗客の降乗りの所要時間を短縮でき、全体の輸送効率を向上できる。

【００５１】なお、本発明は上述した実施形態に限定されるものではない。例えば管理センタ２１のデータ処理

9

装置２３や列車１１の送信データ作成装置１４における各データ処理を実行する制御プログラムは例えばＦＤ（フロッピーディスク）やＣＤ－ＲＯＭ等の記録媒体から供給することも可能である。

【００５２】

【発明の効果】以上説明したように本発明の列車混雑度表示方法及び列車混雑度表示システムにおいては、現在駅における各車両の乗客重量を連続測定して、次駅における各車両から乗客が降りた後の残留乗客数を予測し、この残留乗客数を混雑状況として次駅に表示している。

【００５３】したがって、次駅のホームにいる列車待ちの客に対して、これから乗車しようとする車両の乗車時点における正確な混雑状況を把握できるより有用な情報を提供でき、かつ鉄道会社にとっても１列車内における各車両相互間の乗車率を均一化でき、全体としての輸送効率を向上できる。

【図面の簡単な説明】

【図１】　本発明の一実施形態の列車混雑度表示方法が採用された列車混雑度表示システムの概略構成を示す模式図

【図２】　同実施形態システムにおける駅のホームに対する表示器の配設位置を示す図

10

【図３】　同表示器の表示内容を示す図

【図４】　各列車の駅に到着してから出発するまでの各車両の乗客重量特性図

【図５】　同実施形態システムのデータベースの記憶内容を示す図

【図６】　同実施形態システムの列車における送信データ作成装置の動作を示す流れ図

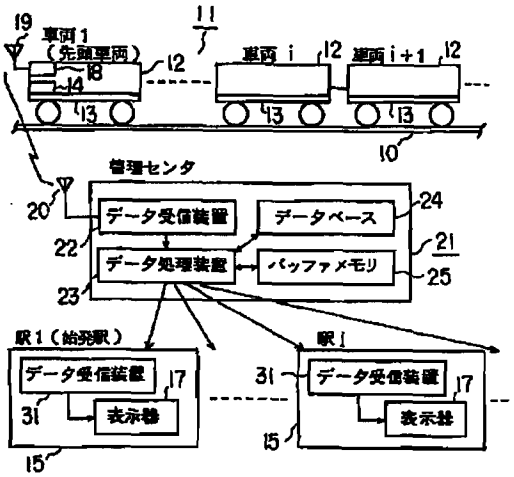
【図７】　同実施形態システムの管理センタにおけるデータ処理装置の動作を示す流れ図

【図８】　従来の各車両の混雑度表示手法を示す図

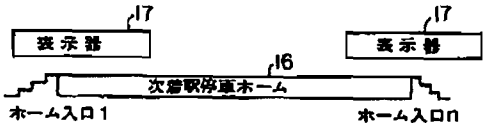
【符号の説明】

１１…列車
１２…車両
１３…重量計
１４…送信データ作成装置
１５…駅
１６…ホーム
１７…表示器
２１…管理センタ
２３…データ処理装置
２４…データベース
２８…実績降車客数メモリ

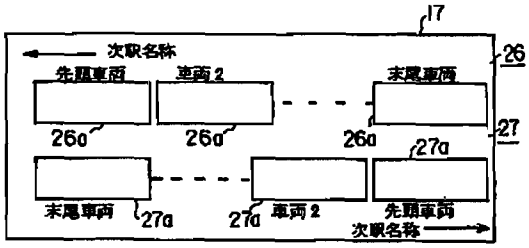
【図１】



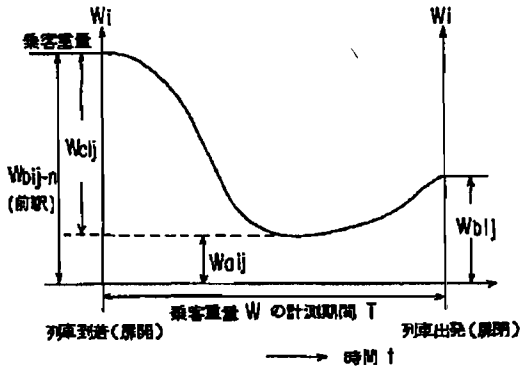
【図２】



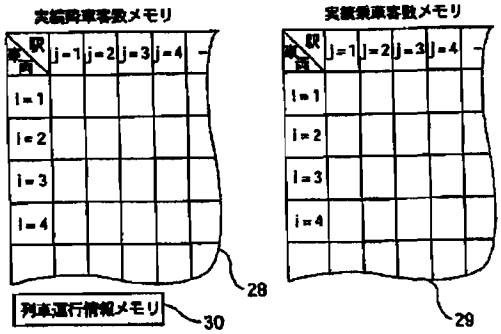
【図３】



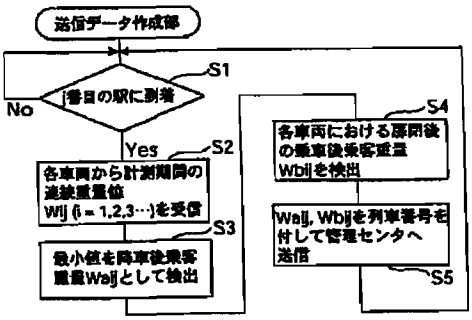
【図４】


Wi
乗客重量
Wi
Wclj
Wbij-n
(前駅)
Wblj
Walj
乗客重量 W の計測期間 T
列車到着(扉開)
列車出発(扉閉)
時間 t

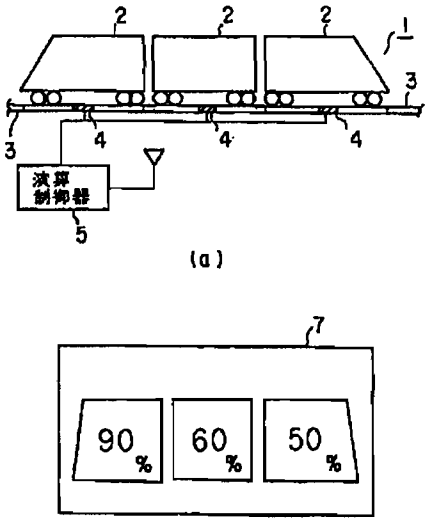
【図５】


実載降車客数メモリ
実載乗車客数メモリ
車両
駅
j=1
j=2
j=3
j=4
i=1
i=2
i=3
i=4
28
29
列車運行情報メモリ
30

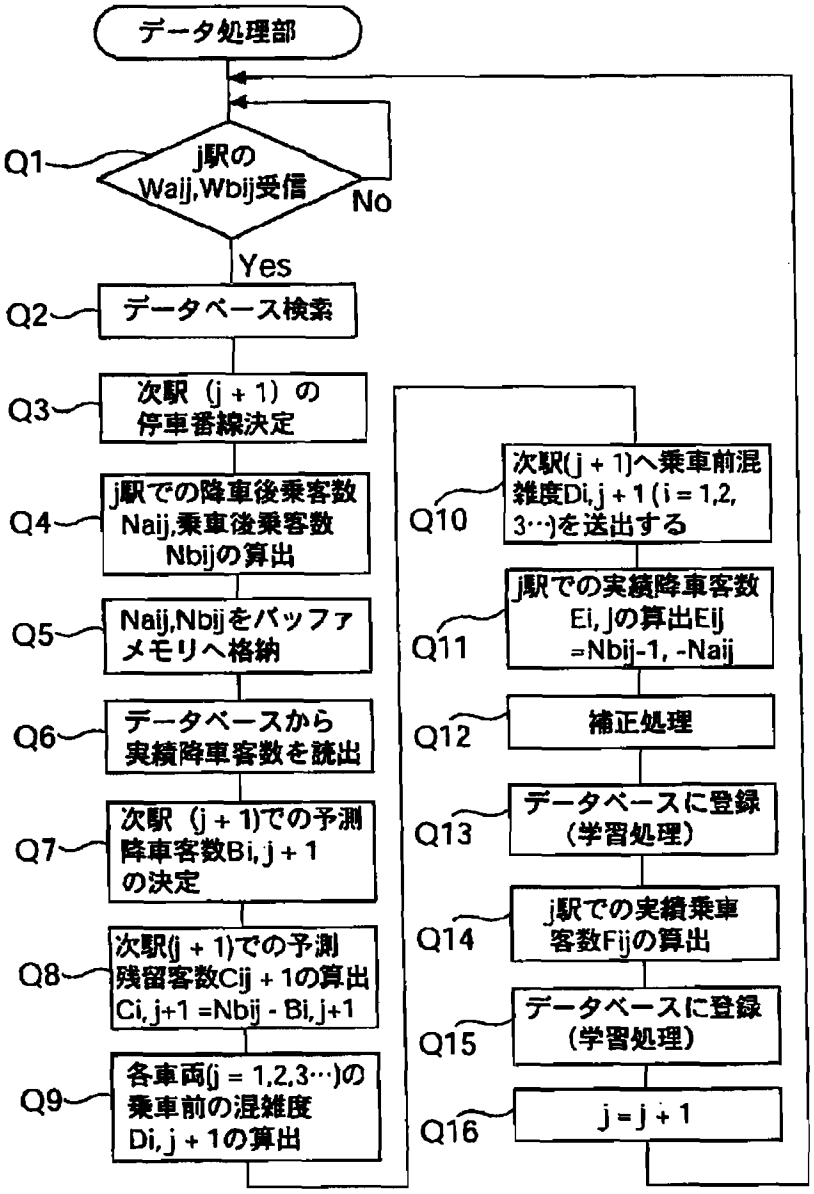
【図６】


送信データ作成部
S1
i番目の駅に到着
No
Yes
S2
各車両から計測期間の
連続重量値
Wij (i = 1,2,3…)を受信
S3
最小値を降車後乗客
重量Walとして検出
S4
各車両における扉閉後
の乗車後乗客重量
Wbijを検出
Walj, Wbijを列車番号を
付して管理センタへ
送信
S5

【図８】


2
2
2
1
3
4
4
4
3
演算
制御器
5
(a)
7
90 %
60 %
50 %
(b)

【図７】


データ処理部
Q1
j駅の
Waij,Wbij受信
No
Yes
Q2
データベース検索
Q3
次駅（j＋1）の
停車番線決定
Q4
j駅での降車後乗客数
Naij,乗車後乗客数
Nbijの算出
Q5
Naij,Nbijをバッファ
メモリへ格納
Q6
データベースから
実績降車客数を読出
Q7
次駅（j＋1)での予測
降車客数Bi,j＋1
の決定
Q8
次駅(j＋1)での予測
残留客数Cij＋1の算出
Ci,j+1 =Nbij - Bi,j+1
Q9
各車両(j＝1,2,3…)の
乗車前の混雑度
Di,j＋1の算出
Q10
次駅(j＋1)へ乗車前混
雑度Di,j＋1(i＝1,2,
3…)を送出する
Q11
j駅での実績降車客数
Ei,jの算出Eij
=Nbij-1, -Naij
Q12
補正処理
Q13
データベースに登録
（学習処理）
Q14
j駅での実績乗車
客数Fijの算出
Q15
データベースに登録
（学習処理）
Q16
j＝j＋1

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 11-192948

(43)Date of publication of application : 21.07.1999

(51)Int.Cl. B61L 23/14
B60L 15/40

(21)Application number : 09-366956

(22)Date of filing : 26.12.1997

(71)Applicant : TOSHIBA CORP

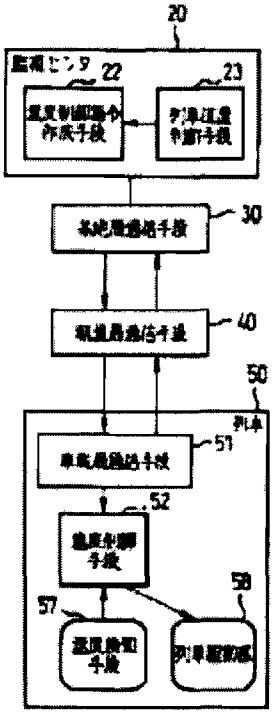
(72)Inventor : MITSUYOSHI KYO
KANAYAMA MICHITAKA

(54) RAILWAY CONTROL DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a railway control device whereby investment in equipment of various facilities and a running cost related to train operation can be reduced.

SOLUTION: Information giving/receiving between a monitoring center 20 monitor controlling a train and a train 50 are performed by a base station communication means 30 and an on-vehicle station communication means 51 through a track station communication means 40 provided in a track. In the monitoring center 20, when passing of the train 50 is detected in the track station communication means 40, a train position is judged by a train position judging means 23, in a train control command forming means 22, a speed control command value of the following train is formed from train position information caught by the train position judging means 23. On the other hand, in the train 50, in a speed control means 57, speed control of the train 50 is performed by a speed control command value formed in the speed control command forming means 22 and a train speed detected in the speed control means 57.



(19)日本国特許庁（ＪＰ）　(12)公開特許公報（Ａ）　(11)特許出願公開番号

特開平11－192948

(43)公開日　平成11年(1999)７月21日

(51)Int.Cl.[6]	識別記号	ＦＩ	
Ｂ６１Ｌ　23/14		Ｂ６１Ｌ　23/14	Ａ
Ｂ６０Ｌ　15/40		Ｂ６０Ｌ　15/40	Ｃ

審査請求　未請求　請求項の数10　ＦＤ　（全 13 頁）

(21)出願番号　特願平9－366956

(22)出願日　平成９年(1997)12月26日

(71)出願人　000003078
株式会社東芝
神奈川県川崎市幸区堀川町72番地

(72)発明者　三吉　京
東京都府中市東芝町１番地　株式会社東芝府中工場内

(72)発明者　金山　道王
東京都府中市東芝町１番地　株式会社東芝府中工場内

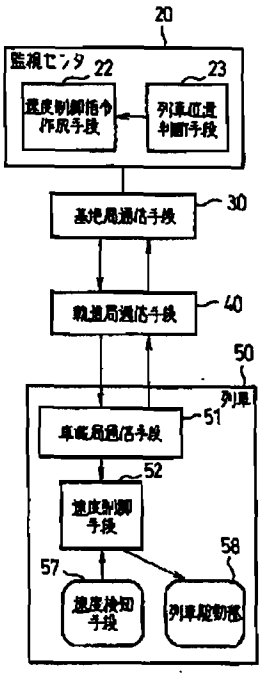
(74)代理人　弁理士　紋田　誠

(54)【発明の名称】　鉄道制御装置

(57)【要約】

【課題】　列車運行に関わる諸設備の設備投資やランニングコストを低減できる鉄道制御装置を提供することである。

【解決手段】　列車を監視制御する監視センタ２０と列車５０との間の情報授受は、軌道１に設けられた軌道局通信手段４０を介して基地局通信手段３０と車載局通信手段５１とで行われる。監視センタ２０では、軌道局通信手段４０が列車５０の通過を検知したときは列車位置判断手段２３により列車位置を判断し、列車制御指令作成手段２２は列車位置判断手段２３により把握した列車位置情報から後続列車の速度制御指令値を作成する。一方、列車５０では、速度制御手段５７は、速度制御指令作成手段２２で作成された速度制御指令値と速度検知手段５７で検知した列車速度により列車５０の速度制御を行なう。



1

【特許請求の範囲】

【請求項１】　軌道上を運行する列車を監視制御する監視センタと、前記軌道に設置され列車との情報授受を行なうための軌道局通信手段と、前記軌道局通信手段を経由して前記監視センタからの制御情報を前記列車に送信したり前記列車からの情報を受信する基地局通信手段と、前記監視センタに設けられ前記軌道局通信手段により列車の通過を検知して列車の位置を判断する列車位置判断手段と、前記監視センタに設けられ前記列車位置判断手段により把握した列車位置情報から後続列車の速度制御指令値を作成する速度制御指令作成手段と、前記列車に設けられ前記軌道局通信手段と情報授受を行う車載局通信手段と、前記列車に設けられ列車の速度を検知する速度検知手段と、前記速度制御指令作成手段で作成された速度制御指令値と前記速度検知手段で検知した列車速度により列車の速度制御を行なう速度制御手段とを備えたことを特徴とする鉄道制御装置。

【請求項２】　請求項１の発明において、前記速度制御手段の代わりに前記速度制御指令作成手段で作成された速度制御指令値を表示するための速度制御指令値表示手段を設け、列車の運転は前記速度制御指令値表示手段により表示される速度制御指令値を参照して運転士が行なうことを特徴とする鉄道制御装置。

【請求項３】　請求項１の発明において、前記列車内に、次駅への到着時刻を予測する到着時刻予測手段と、前記到着時刻予測手段で予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを設けたことを特徴とする鉄道制御装置。

【請求項４】　請求項１の発明において、前記監視センタに設けられ前記列車の通過時刻からその列車の次駅への到着時刻を作成する到着時刻作成手段と、駅に設けられ前記監視センタからの列車の到着時刻情報を受けて案内情報を作成する情報提供内容作成手段と、駅に設けられ前記情報提供内容作成手段で作成された列車の到着時刻の案内情報を旅客に音声出力もしくは文字図形の表示出力で提供する駅案内情報出力手段とを備えたことを特徴とする鉄道制御装置。

【請求項５】　請求項４の発明において、前記列車に設けられ前記列車の乗車人数を検知する乗車人数検知手段と、前記監視センタに設けられ前記乗車人数検知手段で検知し収集した各列車の乗車人数に基づいて営業管理を行なう営業管理手段とを備え、前記駅案内情報出力手段には列車の混雑度も出力するようにしたことを特徴とする鉄道制御装置。

【請求項６】　請求項４の発明において、前記監視センタに設けられ前記到着時刻作成手段により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する運行間隔調整手段と、前記列車に設けられ前記運行間隔調整手段で調整された運行間隔に基づいて各列車の出発時刻を制御する出発時刻制御手段と、前

2

記列車に設けられ前記出発時刻制御手段により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを備えたことを特徴とする鉄道制御装置。

【請求項７】　請求項１の発明において、列車に設けられその列車の走行したキロ数を積算する走行キロ積算手段と、前記監視センタに設けられ前記走行キロ積算手段により算出した列車の走行キロ数を前記軌道局通信手段を経由して入力し列車の保守スケジュールを作成する保守スケジュール作成手段と、車両基地に設けられ前記保守スケジュール作成手段からの列車の保守スケジュールに基づいて保守作業を管理する保守作業管理手段とを備えたことを特徴とする鉄道制御装置。

【請求項８】　請求項７の発明において、列車の故障情報を作成する故障情報作成手段を列車に設け、故障情報作成手段で作成された列車の故障情報を前記軌道局通信手段を経由して監視センタの保守スケジュール作成手段に送信し、保守スケジュール作成手段は故障情報も加味して保守スケジュールを作成することを特徴とする鉄道制御装置。

【請求項９】　請求項１の発明において、前記軌道上に前記列車の速度を検出する軌道上速度検知手段を設け、前記列車に設けられた速度検知手段により検知された列車速度に代えて、前記軌道上速度検知手段により検知された列車速度を前記軌道局通信手段を経由して前記監視センタに送信することを特徴とする鉄道制御装置。

【請求項１０】　請求項１の発明において、前記監視センタに、前記列車の駆動用電源を供給する変電所の積算電力量を監視する電力管理手段を設け、前記速度制御指令作成手段は前記電力管理手段の出力に基づいて速度制御指令値を作成することを特徴とする鉄道制御装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、軌道上を複数の列車が運行する鉄道の各列車の運行を監視制御する鉄道制御装置に関する。

【０００２】

【従来の技術】例えば、鉄道においては軌道上を複数の列車が運行し、その運行する各列車が安全に運行できるように監視制御している。鉄道は停止距離が長いので、安全面と効率面とから列車群の運行を制御する。その運行の制御方式としては閉塞方式が採用されている。この閉塞方式は、線路をいくつかの区間に分けて、一つの区間には１台の列車しか入れないという方法で、列車同士の衝突を防止するものである。

【０００３】図１２は、従来の軌道回路を用いた列車制御方式の説明図である。軌道１上を列車５０は走行し、軌道１には信号機１０１が設けられると共に、列車５０の有無を検知する軌道回路１０２と呼ばれる列車検知装置が設けられている。すなわち、閉塞方式では、軌道１

3

を分割して複数の軌道回路１０２を設け、どの区間に列車がいるかを軌道回路１０２により常時検知するようにしている。そして、その軌道回路１０２の両端部には信号機１０１が設けられ、列車同士の衝突を防止するようにしている。この場合、列車の運転間隔を縮めることができるようにするためには、軌道回路１０２の区間を短くして、列車５０に速度制限を与えることにより、列車５０は、より高密度に運行できるようになる。

【０００４】また、列車制御方式としては、列車の位置を軌道回路１０２を用いないで把握し制御するようにしたものもある。この列車制御方式は、列車の速度検出装置で検出した速度を積分することによって列車の位置を列車内で把握し、列車対地上局の無線通信で列車制御システムに伝達する。そして、列車制御システムでは各列車の制限速度信号を作成し、各列車に伝達するようにしている。このような列車制御方式では、列車の位置は軌道回路１０２を用いないので、連続的に列車位置を列車から地上局に送信している。

【０００５】一方、軌道回路１０２による列車検知方式は、軌道１に電流を流し、列車が存在する場合にはその軌道電流が短絡することで列車の有無を判断するものであるが、列車の識別まではできない。従って、列車群の運行管理を行なうためには、別に列車識別装置を設置する必要がある。

【０００６】図１３は、その列車識別装置の説明図である。列車識別装置は、軌道１の地上側に設置される地上子１０３と、列車５０の車上側に設置される車上子１０４とを有している。列車５０が列車識別装置地上子１０３を通過した時に列車識別装置車上子１０４との間で、電磁誘導により列車の識別番号を授受する。このほか、列車識別装置としては、駅ホームで列車に設けられたバーコードを読み取る方式もある。

【０００７】また、列車は走行したキロ数などに応じて点検保守を行なうことが義務づけられているが、従来は、列車の運行計画と並行して列車の運用計画とならべて保守スケジュールを作成し保守してきた。

【０００８】

【発明が解決しようとする課題】ところが、フルオートマティックな列車運行を実現するためには、列車運行に関わる諸設備を統合することが望まれるが、鉄道業界では今後の乗客数の大きな伸びも見込めず、設備費や保守費の削減が重要である。

【０００９】軌道回路を用いた列車制御方式では路線全線にわたっての保守が必要でありコストがかかるといった課題があり、列車の位置を軌道回路１０２を用いないで把握する列車制御方式では連続的に列車位置を列車から地上局に送信する必要がある。また、それぞれの列車制御方式が並列の形で採用され、それぞれに必要な設備が個々に設置されているために独立分散の意味では利点があるが、設備投資、維持や保守の面で無駄があるといった課題がある。

4

【００１０】本発明の目的は、列車運行に関わる諸設備の設備投資やランニングコストを低減できる鉄道制御装置を提供することである。

【００１１】

【課題を解決するための手段】請求項１の発明に係わる鉄道制御装置は、軌道上を運行する列車を監視制御する監視センタと、軌道に設置され列車との情報授受を行なうための軌道局通信手段と、軌道局通信手段を経由して監視センタからの制御情報を列車に送信したり列車からの情報を受信する基地局通信手段と、監視センタに設けられ軌道局通信手段により列車の通過を検知して列車の位置を判断する列車位置判断手段と、監視センタに設けられ列車位置判断手段により把握した列車位置情報から後続列車の速度制御指令値を作成する速度制御指令作成手段と、列車に設けられ軌道局通信手段と情報授受を行う車載局通信手段と、列車に設けられ列車の速度を検知する速度検知手段と、速度制御指令作成手段で作成された速度制御指令値と速度検知手段で検知した列車速度により列車の速度制御を行なう速度制御手段とを備えたことを特徴とする。

【００１２】請求項１の発明に係わる鉄道制御装置では、列車を監視制御する監視センタと列車との間の情報授受は、軌道に設けられた軌道局通信手段を介して基地局通信手段と車載局通信手段とで行われる。そして、監視センタでは、軌道局通信手段が列車の通過を検知したときは列車位置判断手段により列車の位置を判断し、列車制御指令作成手段は列車位置判断手段により把握した列車位置情報から後続列車の速度制御指令値を作成する。一方、列車では、速度制御手段は、監視センタの速度制御指令作成手段で作成された速度制御指令値と列車の速度検知手段で検知した列車速度により列車の速度制御を行なう。

【００１３】請求項２の発明に係わる鉄道制御装置は、請求項１の発明において、速度制御手段の代わりに速度制御指令作成手段で作成された速度制御指令値を表示するための速度制御指令値表示手段を設け、列車の運転は速度制御指令値表示手段により表示される速度制御指令値を参照して運転士が行なうことを特徴とする。

【００１４】請求項２の発明に係わる鉄道制御装置では、請求項１の発明での自動運転に代えて、列車の運転は、運転士により手動で行われる。その際、運転士は速度制御指令値表示手段により表示される速度制御指令値を参照して列車の運転を行う。

【００１５】請求項３の発明に係わる鉄道制御装置は、請求項１の発明において、列車内に、次駅への到着時刻を予測する到着時刻予測手段と、到着時刻予測手段で予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを設けたことを特徴とする。

5

【００１６】請求項３の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、列車内の到着時刻予測手段で次駅への到着時刻を予測し、案内情報出力手段により予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する。

【００１７】請求項４の発明に係わる鉄道制御装置は、請求項１の発明において、監視センタに設けられ列車の通過時刻からその列車の次駅への到着時刻を作成する到着時刻作成手段と、駅に設けられ監視センタからの列車の到着時刻情報を受けて案内情報を作成する情報提供内容作成手段と、駅に設けられ情報提供内容作成手段で作成された列車の到着時刻の案内情報を旅客に音声出力もしくは文字図形の表示出力で提供する駅案内情報出力手段とを備えたことを特徴とする。

【００１８】請求項４の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、監視センタの到着時刻作成手段は列車の通過時刻からその列車の次駅への到着時刻を作成し、駅の情報提供内容作成手段によりその列車の到着時刻の案内情報を作成する。作成された列車の到着時刻の案内情報は、駅案内情報出力手段により旅客に音声出力もしくは文字図形の表示出力で提供される。

【００１９】請求項５の発明に係わる鉄道制御装置は、請求項４の発明において、列車に設けられ列車の乗車人数を検知する乗車人数検知手段と、監視センタに設けられ乗車人数検知手段で検知し収集した各列車の乗車人数に基づいて営業管理を行なう営業管理手段とを備え、駅案内情報出力手段には列車の混雑度も出力するようにしたことを特徴とする。

【００２０】請求項５の発明に係わる鉄道制御装置では、請求項４の発明の作用に加え、列車の乗車人数検知手段で検知し収集した各列車の乗車人数に基づいて、監視センタの営業管理手段は営業管理を行い、駅案内情報出力手段に列車の混雑度も出力する。

【００２１】請求項６の発明に係わる鉄道制御装置は、請求項４の発明において、監視センタに設けられ到着時刻作成手段により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する運行間隔調整手段と、列車に設けられ運行間隔調整手段で調整された運行間隔に基づいて各列車の出発時刻を制御する出発時刻制御手段と、列車に設けられ出発時刻制御手段により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段とを備えたことを特徴とする。

【００２２】請求項６の発明に係わる鉄道制御装置では、請求項４の発明の作用に加え、監視センタの運行間隔調整手段は、到着時刻作成手段により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する。列車の出発時刻制御手段は、運行間隔調整手段で調整された運行間隔に基づいて各列車の出発時刻を制御し、列車の案内情報出力手段に出発時刻制御手段により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する。

6

【００２３】請求項７の発明に係わる鉄道制御装置は、請求項１の発明において、列車に設けられその列車の走行したキロ数を積算する走行キロ積算手段と、監視センタに設けられ走行キロ積算手段により算出した列車の走行キロ数を軌道局通信手段を経由して入力し列車の保守スケジュールを作成する保守スケジュール作成手段と、車両基地に設けられ保守スケジュール作成手段からの列車の保守スケジュールに基づいて保守作業を管理する保守作業管理手段とを備えたことを特徴とする。

【００２４】請求項７の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、監視センタの保守スケジュール作成手段は、列車の走行キロ積算手段により算出した列車の走行キロ数を軌道局通信手段を経由して入力し列車の保守スケジュールを作成する。車両基地の保守作業管理手段は保守スケジュール作成手段からの列車の保守スケジュールに基づいて保守作業を管理する。

【００２５】請求項８の発明に係わる鉄道制御装置は、請求項７の発明において、列車の故障情報を作成する故障情報作成手段を列車に設け、故障情報作成手段で作成された列車の故障情報を軌道局通信手段を経由して監視センタの保守スケジュール作成手段に送信し、保守スケジュール作成手段は故障情報も加味して保守スケジュールを作成することを特徴とする。

【００２６】請求項８の発明に係わる鉄道制御装置では、請求項７の発明の作用に加え、保守スケジュール作成手段は故障情報も加味して保守スケジュールを作成する。

【００２７】請求項９の発明に係わる鉄道制御装置は、請求項１の発明において、軌道上に列車の速度を検出する軌道上速度検知手段を設け、列車に設けられた速度検知手段により検知された列車速度に代えて、軌道上速度検知手段により検知された列車速度を軌道局通信手段を経由して監視センタに送信することを特徴とする。

【００２８】請求項９の発明に係わる鉄道制御装置では、請求項１の発明の作用に代えて、軌道上速度検知手段により検知された列車速度を軌道局通信手段を経由して監視センタに送信し、列車の車載局通信手段の負荷を軽減する。

【００２９】請求項１０の発明に係わる鉄道制御装置は、請求項１の発明において、監視センタに、列車の駆動用電源を供給する変電所の積算電力量を監視する電力管理手段を設け、速度制御指令作成手段は電力管理手段の出力に基づいて速度制御指令値を作成することを特徴とする。

【００３０】請求項１０の発明に係わる鉄道制御装置では、請求項１の発明の作用に加え、列車の駆動用電源を供給する変電所の積算電力量が所定値を越えたときは、

電力管理手段は速度制御指令作成手段に対し速度を減速し電力消費を軽減させる指令を出力する。

【００３１】

【発明の実施の形態】以下、本発明の実施の形態を説明する。図１１は本発明の鉄道制御装置を鉄道システムに適用した場合の構成図である。図１１に示す鉄道システムは、都市内を走行する延長１０ｋｍ～２０ｋｍ程度の規模のレール式交通システムであり、列車５０は軌道１上を走行し駅７０で停車する運転を行っている。監視センタ２０は路線の近傍に設置され、軌道１に設けられた軌道局通信手段４０とデータの送受信を行う基地局通信手段３０を有する。

【００３２】軌道上には複数個の軌道局通信手段４０が設置され、列車５０の情報は軌道局通信手段４０を経て基地局通信手段３０に通信され、監視センタ２０に送られる。列車５０と軌道局通信手段４０との間は、電磁誘導や空間波を用いた無線伝送を行い、データの送受信を行う。また、基地局通信手段３０と軌道局通信手段４０との間は、空間波を用いた無線伝送でデータ伝送を行う。軌道局通信手段４０は、ここでは駅７０間に１個乃至数個設置されたものを示している。また、軌道１には分岐装置７が設けられ、を介して列車５０を車両基地８０に導くようになっている。

【００３３】次に、図１は本発明の第１の実施の形態に係わる鉄道制御装置のブロック構成図である。監視センタ２０は軌道上を運行する列車を監視制御するものであり、基地局通信手段３０および軌道局通信手段４０を介して列車５０とデータの送受信を行う。監視センタ２０は基地局通信手段３０と有線で結合し、基地局通信手段３０と軌道局通信手段４０との間、および軌道局通信手段４０と車載局通信手段５１との間は無線で結合している。なお、基地局通信手段３０と軌道局通信手段４０の間は通信ケーブルを用いて結合しても良いことは言うまでもない。

【００３４】監視センタ２０は速度制御指令作成手段２２と列車位置判断手段２３とを有しており、列車位置判断手段２３は、列車５０が軌道局通信手段４０を通過した情報に基づいて列車の位置を判断するものである。一方、速度制御指令手段２２は列車位置判断手段２３により把握した列車位置情報から後続列車の速度制御指令値を作成するものである。

【００３５】列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８とが設けられている。速度制御手段５２は、車載局通信手段５１を介して入力した監視センタ２０の速度制御指令作成手段２２で作成された速度制御指令値と、速度検知手段５７で検知した列車速度とを比較し、列車の速度制御を行なう。すなわち、列車速度が速度制御指令になるように列車駆動部５８に列車の駆動指令を出力する。これにより、後続列車の速度を自動制御する。

【００３６】軌道局通信手段４０は、列車５０が軌道局通信手段４０を通過する時に列車５０から送信された列車識別番号を識別すると共に通過時刻を検出する。また、列車の速度検知手段５７で検知した列車速度は車載局通信手段５１を介して軌道局通信手段４０に伝送される。軌道局通信手段４０では、列車識別番号、列車速度および列車通過時刻に加え、軌道局通信手段４０の識別番号を基地局通信手段３０に伝送する。

【００３７】監視センタ２０内の列車位置判断手段２３では、列車５０の突入した路線上の区間を判断し通過時刻とともに記憶する。例えば、図１１の列車５０ａの場合、軌道局通信手段４０ｄの通過の情報より、列車５０ａの突入した路線上の区間（４０ｄ－４０ｅ）を判断し、軌道局通信手段４０ｄの列車通過時刻とともに記憶する。そして、速度制御指令作成手段２２により、接続する後ろの区間（４０ｃ－４０ｄ）に他の列車が入る場合の目標速度である速度制御指令値を次式で作成する。

【００３８】

【数１】

$$Vref(nk) = \min(V(nk), V^*(nk))$$

$$V^*(nk) = \sqrt{((Xp - xp - X) \times 2 \times a(nk) \times 3600/1000)}$$

ただし、

Vref(nk)　：列車 nk の速度指令値[km/h]

V(nk)　：列車 nk の現在速度[km/h]

V*(nk)　：列車 nk の減速目標値[km/h]

Xp　：軌道局通信手段 p の位置[m]

X　：列車現在位置[m]

xp　：余裕距離[m]

a(nk)　：列車 nk の設定減速度[(km/h)/s]

【００３９】軌道局通信手段４０の設置間隔の短い場合には、軌道局通信手段４０をまたがって速度指令値を算出することになる。この速度制御指令値の作成動作は、いずれかの列車がいずれかの軌道局通信手段４０を通過したタイミングで実施する。

【００４０】一方、列車５０ａは、軌道局通信手段４０ｄ通過時に、速度制御指令作成手段２２により同様に算出されていた区間４０ｄ－４０ｅの速度制御指令値を軌道局通信手段４０ｄより車載局通信手段５１を介して受け取り、速度制御手段５２により速度検知手段５７で検知した自列車の速度と照合させ、検知速度が速度制御指令値を上回る時は列車駆動部５８に対してブレーキ操作を指示し、下回る時は力行を指示することにより自列車の速度を制御する。

【００４１】この第１の実施の形態によれば、後続の列車の速度指令値を先行する列車の位置に基づいて算出し、後続の列車の速度を自動制御するので安全性が向上する。また、どの区間にどの列車が存在するかを軌道局通信手段４０で検知するので設備が合理化できる。ま

9

た、列車の運転間隔に応じて軌道局通信手段４０の設置個数を少なくすることができ、しかも駅構内に設置することにより、保守を簡単化できる。

【００４２】次に、本発明の第２の実施の形態を説明する。図２は本発明の第２の実施の形態に係わる鉄道制御装置のブロック構成図である。この第２の実施の形態は、図１に示した第１の実施の形態に対し、速度制御手段５２の代わりに速度制御指令作成手段２２で作成された速度制御指令値を表示するための速度制御指令値表示手段６３を設け、列車の運転は速度制御指令値表示手段６３により表示される速度制御指令値を参照して運転士が行なうようにしたものである。

【００４３】監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３とが設けられ、列車５０内には、車載局通信手段５１と速度制御指令値表示手段６３と速度検知手段５７と列車駆動部５８とが設けられている。

【００４４】第１の実施の形態では列車５０は自動運転されるが、この第２の実施の形態では列車５０の操縦は運転士が行なう。そのために速度制御手段５２の代わりに速度制御指令値表示手段６３が設けられ、運転士は速度制御指令値表示手段６３により表示される速度制御指令値を参照して運転を行なうことになる。

【００４５】この第２の実施の形態では、システムダウン時などの特殊運転状況下においても、速度制御指令値表示手段６３により、運転士による目視運転が実施でき列車を走行させることができる。

10

【００４６】次に、本発明の第３の実施の形態を説明する。図３は本発明の第３の実施の形態に係わる鉄道制御装置のブロック構成図である。この第３の実施の形態は、図１に示した第１の実施の形態に対し、列車５０内に、次駅への到着時刻を予測する到着時刻予測手段５３と、到着時刻予測手段５３で予測した到着予測時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段５９とを追加して設けたものである。

【００４７】監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３とが設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７に加え、到着時刻予測手段５３と案内情報出力手段５９とが設けられている。

【００４８】列車５０内では、監視センタ２０から指示された列車５０の速度制御指令値に基づき、次駅への到着時刻を次のように予測する。まず、軌道局通信手段４０の各ポイントについて、標準速度で走行した場合の次駅までの走行時間を記憶しておく。次駅到着予測時刻T(m,k,nk)は、次式で算出する。

【００４９】

【数２】

$$T(m,k,nk) = T0 + t^*(m,k,nk) \times V^*(m,k) / V(nk) \quad \cdots(1)$$

ただし、

T(m,k,nk)：m駅へのk時間帯のnk番目の列車の次駅到着予測時刻

T0　　：現在時刻

t*(m,k,nk)：m駅へのk時間帯の次駅までの標準走行時間[秒]

V(nk)　：列車nkの速度制御指令値[km/h]

V*(m,k)　：m駅k時間帯の標準速度[km/h]

【００５０】そして、上式で算出した次駅到着予測時刻T(m,k,nk)を、列車内の案内情報出力手段５９に表示する。

【００５１】この第３の実施の形態によれば、列車遅延発生時にも旅客に対して的確に列車運転状況をアナウンスすることができ、乗務員なしの運転が可能となる。

【００５２】次に、本発明の第４の実施の形態を説明する。図４は本発明の第４の実施の形態に係わる鉄道制御装置のブロック構成図である。この第４の実施の形態は、図１に示した第１の実施の形態に対し、列車５０の通過時刻からその列車５０の次駅への到着時刻を作成する到着時刻作成手段２４を監視センタ２０に追加して設け、基地局通信手段３０とデータの授受を行う軌道局通信手段４０と、監視センタ２０からの列車の到着時刻情報を受けて案内情報を作成する情報提供内容作成手段７２と、情報提供内容作成手段７２で作成された列車の到着時刻の案内情報を旅客に音声出力もしくは文字図形の表示出力で提供する駅案内情報出力手段７３とを駅に追加して設けたものである。

【００５３】図４において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と到着時刻作成手段２４とが設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８が設けられている。また、駅７０には、軌道局通信手段４０と情報提供内容作成手段７２と駅案内情報出力手段７３が設けられている。

【００５４】監視センタ２０の到着時刻作成手段２４は、列車５０の通過時刻からその列車の次駅への到着時刻を作成し、駅７０の情報提供内容作成手段７２によりその列車５０の到着時刻の案内情報を作成する。作成された列車５０の到着時刻の案内情報は、駅案内情報出力手段７３により旅客に音声出力もしくは文字図形の表示出力で提供される。

【００５５】すなわち、監視センタ２０では、速度制御

11

指令作成手段２２で作成した速度制御指令に基づき到着時刻作成手段２４により全列車の到着時刻を作成し、駅７０に設置してある軌道局通信手段４０を介して情報提供内容作成手段７２に伝送し、駅案内情報出力手段７３に表示する。

【００５６】この第４の実施の形態によれば、駅５０において次の列車の到着予測時刻を表示するので、駅７０で列車５０を待つ乗客に列車運行に関する適切なアナウンスを行なうことができ、駅員の無人化を図ることができる。

【００５７】次に、本発明の第５の実施の形態を説明する。図５は本発明の第５の実施の形態に係わる鉄道制御装置のブロック構成図である。この第５の実施の形態は、図４に示した第４の実施の形態に対し、列車の乗車人数を検知する乗車人数検知手段５６を列車５０内に追加して設け、乗車人数検知手段５６で検知し収集した各列車５０の乗車人数に基づいて営業管理を行なう営業管理手段２７を監視センタ２０内に設け、駅７０内の駅案内情報出力手段７３には列車５０の混雑度も出力するようにしたものである。

【００５８】図５において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と到着時刻作成手段２４と営業管理手段２７とが設けられている。列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８と乗車人数検知手段５６が設けられている。また、駅７０には、軌道局通信手段４０と情報提供内容作成手段７２と駅案内情報出力手段７３とが設けられている。

【００５９】監視センタ２０では、速度制御指令作成手段２２で作成した速度制御指令に基づき到着時刻作成手段２４により到着時刻を作成し、駅７０に設置してある軌道局通信手段４０を介して情報提供内容作成手段７２に伝送し、駅案内情報出力手段７３に表示する。

【００６０】この際、乗車人数検知手段５６により列車内で測定した各列車の荷重測定装置の出力を乗客の平均体重設定値（例えば５５ｋｇ）で割ることにより乗客数を算出し、乗客数を車載局通信手段５１により軌道局通信手段４０を介して監視センタ２０に送信する。監視センタ２０では、営業管理手段２７により乗客数データの

12

帳票出力、旅客流動解析、運転計画等の営業管理を行なうとともに軌道局通信手段４０を介して駅７０に送信し、駅案内情報として到着する列車の混雑度を表示する。

【００６１】この第５の実施の形態では、列車５０の混雑度を駅７０に表示するので、各区間ごとの乗客数の計数ができ、よりきめ細やかな運転計画、旅客サービスができる。また、乗客数に基づいて列車の運行管理から営業管理までの一元管理が可能となり省力化が図れる。

【００６２】次に、本発明の第６の実施の形態を説明する。図６は本発明の第６の実施の形態に係わる鉄道制御装置のブロック構成図である。この第６の実施の形態は、図４に示した第４の実施の形態に対し、到着時刻作成手段２４により作成された各列車の到着時刻に基づき各列車の運行間隔を算出し運行間隔を調整する運行間隔調整手段を監視センタ２０に追加して設け、この運行間隔調整手段２５で調整された運行間隔に基づいて各列車の出発時刻を制御する出発時刻制御手段５４と、出発時刻制御手段５４により設定された出発時刻を列車内に音声出力もしくは文字図形で表示出力する案内情報出力手段５９とを列車５０に追加して設けたものである。

【００６３】図６において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と到着時刻作成手段２４と運行間隔調整手段２５とが設けられる。列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と出発時刻制御手段５４と案内情報出力手段５９とドア開閉操作部６１とが設けられる。また、駅７０には、軌道局通信手段４０と情報提供内容作成手段７２と駅案内情報出力手段７３とが設けられる。

【００６４】到着時刻作成手段２４で作成した到着時刻を用いて、運行間隔調整手段２５では、各列車の運行間隔がある一定幅になるよう各列車の出発時刻を作成する。この第６の実施の形態では、環状線のように、一日中列車がぐるぐる回っているような路線で運行ダイヤとして運転間隔が設定されているような場合に有効である。各列車の計画出発時刻は次のように決定する。

【００６５】

【数３】

13 14

TS0(m,k,nk) ＞ T0k ＋ nk × td(k) の場合

TS(m,k,nk) = TT(m,k,nk) ＋ en(m,k)

TS0(m,k,nk) ＜ T0k ＋ nk × td(k) の場合

TS(m,k,nk) = T0k ＋ nk × td(k)

ただし、

TS0(m,k,nk) ＝ TT(m,k,nk) ＋ eh(m,k)

TT(m,k,nk) ： m駅のk時間帯のnk列車の到着予測時刻時刻

TS(m,k,nk) ： m駅のk時間帯のnk列車の計画出発時刻

T0k ： k時間帯の初期時刻

td(k) ： k時間帯の運行間隔[秒]

en(m,k) ： 最小停車時間[秒]

eh(m,k) ： 標準停車時間[秒]

【００６６】運行間隔調整手段２５で決定した計画出発時刻は、基地局通信手段３０および軌道局通信手段４０を経由して車載局通信手段５１により列車５０内に伝送される。列車５０内では、出発時刻制御手段５４により受信した計画出発時刻に基づき案内情報出力手段５９に計画出発時刻が表示されるとともに、出発のためのドア開閉操作指令がドア開閉操作部６１に入力され、ドア閉め後力行指令が列車駆動部５８に入力される。また、計画出発時刻は駅７０にも伝送され、駅案内情報出力手段７３に表示される。

【００６７】この第６の実施の形態では、列車５０の運行間隔のバラツキを調整できるので、列車の運行を円滑に行うことができる。すなわち、列車５０の運行間隔のバラツキは、駅７０における乗り降りの混雑などで時間帯ごとにさまざまに発生するが、この第６の実施の形態によれば運行間隔の適正化が自動で行なえる。

【００６８】次に、本発明の第７の実施の形態を説明する。図７は本発明の第７の実施の形態に係わる鉄道制御装置のブロック構成図である。この第７の実施の形態は、図１に示した第１の実施の形態に対し、列車５０の走行したキロ数を積算する走行キロ積算手段５５を列車５０に設け、走行キロ積算手段５５により算出した列車５０の走行キロ数を軌道局通信手段４０を経由して入力し列車５０の保守スケジュールを作成する保守スケジュール作成手段２６を監視センタ２０に設け、保守スケジュール作成手段２６からの列車５０の保守スケジュールに基づいて保守作業を管理する保守作業管理手段８２を車両基地８０に設けたものである。

【００６９】図７において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と保守スケジュール作成手段２６が設けられて、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と走行キロ積算手段５５と列車駆動部５８とが設けられている。また、車両基地８０には、軌道局通信手段４０と保守作業管理手段８２とが設けられている。

【００７０】監視センタ２０の保守スケジュール作成手段２６は、列車５０の走行キロ積算手段５５により算出した列車５０の走行キロ数を軌道局通信手段５１を経由して入力し列車５０の保守スケジュールを作成する。車両基地８０の保守作業管理手段８２は保守スケジュール作成手段２６からの列車５０の保守スケジュールに基づいて保守作業を管理する。

【００７１】すなわち、列車５０は走行キロ数に応じた点検保守作業を実施するために、走行キロ積算手段５５において速度検知手段５７の出力を積分することとにより走行した延べキロ数を算出する。そして、車載局通信手段５１は、列車識別番号、列車速度に加え、走行キロ数を軌道局通信手段４０および基地局通信手段３０を経由して監視センタ２０内の保守スケジュール作成手段２６に送信する。保守スケジュール作成手段２６では、各列車５０の走行キロ数を監視し、保守スケジュール表を埋める形で走行キロ数がしきい値を越えた列車を割り当てていく。一方、保守を行なう列車については、軌道１の分岐制御により車両基地８０へ配送する。

【００７２】この第７の実施の形態によれば、列車５０の位置検知と同時に、監視センタ２０で各列車５０の走行キロ数をオンラインで監視するので、列車５０の統合的な管理が可能となり、システムのコスト削減が図れる。

【００７３】次に、本発明の第８の実施の形態を説明する。図８は本発明の第８の実施の形態に係わる鉄道制御装置のブロック構成図である。この第８の実施の形態は、図７に示した第７の実施の形態に対し、列車の故障情報を作成する故障情報作成手段６２を列車５０に設け、故障情報作成手段６２で作成された列車５０の故障情報を軌道局通信手段４０を経由して監視センタ２０の保守スケジュール作成手段２６に送信し、保守スケジュール作成手段２６は故障情報も加味して保守スケジュールを作成するようにしたものである。

【００７４】図８において、監視センタ２０内には速度

15

制御指令作成手段２２と列車位置判断手段２３と保守スケジュール作成手段２６が設けられ、列車５０内には、車載局通信手段５１と速度制御手段６２と速度検知手段５７と走行キロ積算手段５５と列車駆動部５８と故障情報作成手段６２とが設けられている。また、車両基地８０には、軌道局通信手段４０と保守作業管理手段８２とが設けられている。

【００７５】列車５０に故障が発生した場合に、故障情報作成手段６２により故障の程度、内容などを識別して符号化し、車載局通信手段５１により軌道局通信手段４０および基地局通信手段３を経由して監視センタ２０に送信する。必要に応じて保守スケジュール作成手段２６により保守スケジュールに組み込み、保守スケジュールを基地局通信手段３０を介して車両基地８０に送信する。

【００７６】この第８の実施の形態によれば、列車の位置検知と同時に、監視センタ２０で各列車の故障情報をオンラインで監視し、保守スケジュール作成手段２６により故障情報も加味して保守スケジュールを作成するので、列車５０の統合的な管理が可能となる。また、システムのコスト削減が図れる。

【００７７】次に、本発明の第９の実施の形態を説明する。図９は本発明の第９の実施の形態に係わる鉄道制御装置のブロック構成図である。この第９の実施の形態は、図１に示した第１の実施の形態に対し、軌道上に列車の速度を検出する軌道上速度検知手段４５を設け、列車５０に設けられた速度検知手段５２により検知された列車速度に代えて、軌道上速度検知手段４５により検知された列車速度を軌道局通信手段４０を経由して監視センタ２０に送信するようにしたものである。

【００７８】図９において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３とが設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８とが設けられている。また、軌道１上には軌道上速度検知手段４５が設けられている。

【００７９】車載局通信手段５１では、列車情報として列車識別番号を軌道局通信手段４０に送信する。列車速度は、軌道上の速度検知手段４５により検知した速度を軌道局通信手段４０から基地局通信手段３０を介して監視センタ２０に送信する。

【００８０】請求項９の発明に係わる鉄道制御装置では、請求項１の発明の作用に代えて、軌道上速度検知手段により検知された列車速度を軌道局通信手段を経由して監視センタに送信し、列車の車載局通信手段の負荷を軽減する。

【００８１】この第９の実施の形態では、車載局通信手段５１と軌道局通信手段４０との間の伝送項目を減らすことができ、その分、列車５０内でしか収集できない情報に充てることができる。

16

【００８２】次に、本発明の第１０の実施の形態を説明する。図１０は本発明の第１０の実施の形態に係わる鉄道制御装置のブロック構成図である。この第１０の実施の形態は、図１に示した第１の実施の形態に対し、監視センタ２０に、列車５０の駆動用電源を供給する変電所の積算電力量を監視する電力管理手段２１を設け、速度制御指令作成手段２２は電力管理手段２１の出力に基づいて速度制御指令値を作成するようにしたものである。

【００８３】図１０において、監視センタ２０内には速度制御指令作成手段２２と列車位置判断手段２３と電力管理手段２１が設けられ、列車５０内には、車載局通信手段５１と速度制御手段５２と速度検知手段５７と列車駆動部５８とが設けられている。

【００８４】電力管理手段２１においては、常時各変電所の積算電力量を監視し、契約量を超えることが予想される時には、一時的に省電力モードとし、省電力指令を速度制御指令作成手段２２に出力する。速度制御指令作成手段２２では、省電力指令を受けた場合には最高速度を２０％減少として速度制御指令値を決定する。このように、列車５０の駆動用電源を供給する変電所の積算電力量が所定値を越えたときは、電力管理手段２１は速度制御指令作成手段２２に対し速度を減速し電力消費を軽減させる指令を出力する。これにより、各列車の力行時間が短縮され、積算電力量の増加が抑制できる。

【００８５】

【発明の効果】以上述べたように、本発明によれば、軌道上の拠点に地上子を設け、車上子との間を非接触式で情報通信を行い、列車の通過とその列車の識別番号、混雑情報、保守情報などの列車情報を一括して伝送し、それらの情報を使用して列車の自動運行ダイヤ管理、保守作業の自動スケジューリングを行なうので、設備投資ならびに省力化を含むランニングコストを抑制した鉄道制御装置を得ることができる。

【図面の簡単な説明】

【図１】図１は、本発明の第１の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図２】図２は、本発明の第２の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図３】図３は、本発明の第３の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図４】図４は、本発明の第４の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図５】図５は、本発明の第５の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図６】図６は、本発明の第６の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図７】図７は、本発明の第７の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図８】図８は、本発明の第８の実施の形態に係わる鉄道制御装置のブロック構成図である。

17

【図９】図９は、本発明の第９の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図１０】図１０は、本発明の第１０の実施の形態に係わる鉄道制御装置のブロック構成図である。

【図１１】図１１は、本発明の鉄道制御装置を鉄道システムに適用した場合の構成図である。

【図１２】図１２は、従来の軌道回路を用いた列車制御方式の説明図である。

【図１３】図１３は、従来の列車識別装置の説明図である。

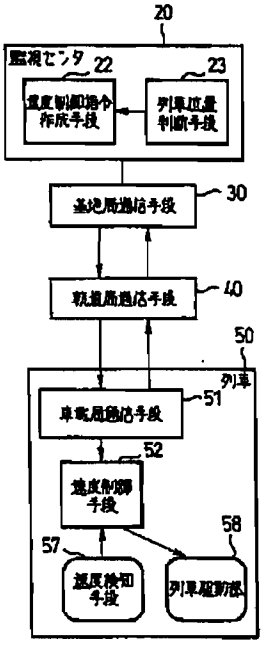
【符号の説明】

１　軌道
２０　監視センタ
２１　電力管理手段
２２　速度制御指令作成手段
２３　列車位置判断手段
２４　到着時刻作成手段
２５　運行間隔調整手段
２６　保守スケジュール作成手段
２７　営業管理手段
３０　基地局通信手段
４０　軌道局通信手段

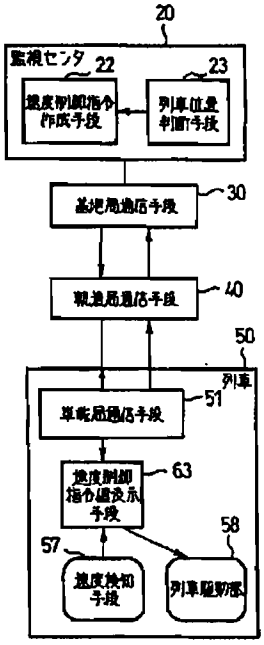
18

４５　軌道上速度検知手段
５０　列車
５１　車載局通信手段
５２　速度制御手段
５３　到着時刻予測手段
５６　乗車人数検知手段
５７　速度検知手段
５８　列車駆動部
５９　案内情報表示手段
６１　ドア開閉操作部
６２　故障情報作成手段
６３　速度制御指令値表示手段
７０　駅
７２　情報提供内容作成手段
７３　駅案内情報出力手段
８０　車両基地
８２　保守作業管理手段
１０１　信号機
１０２　軌道回路
１０３　地上子
１０４　車上子

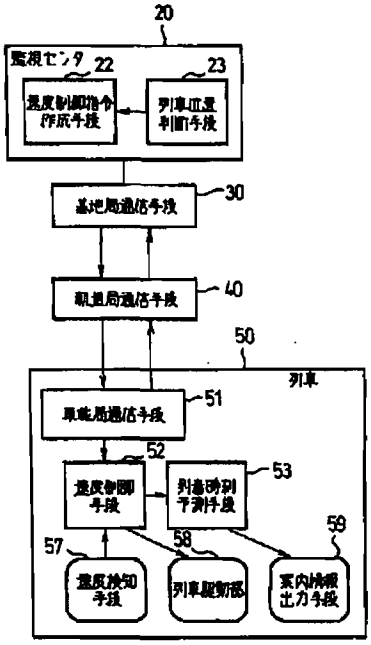
【図１】



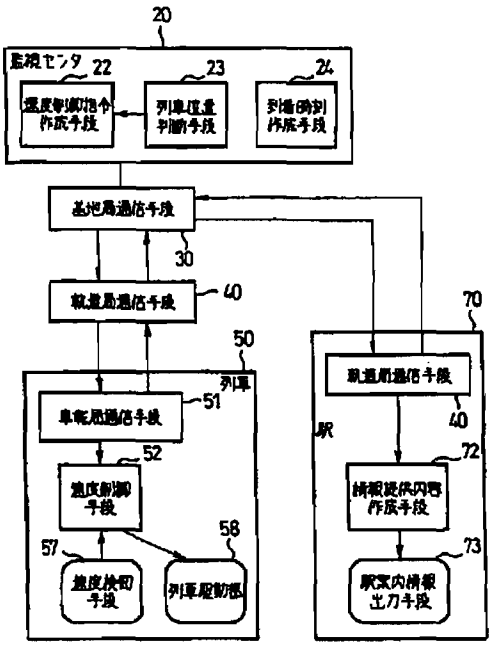
【図２】



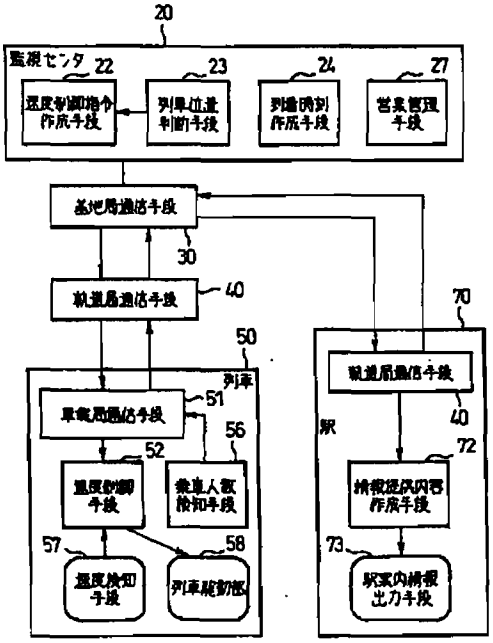
【図３】



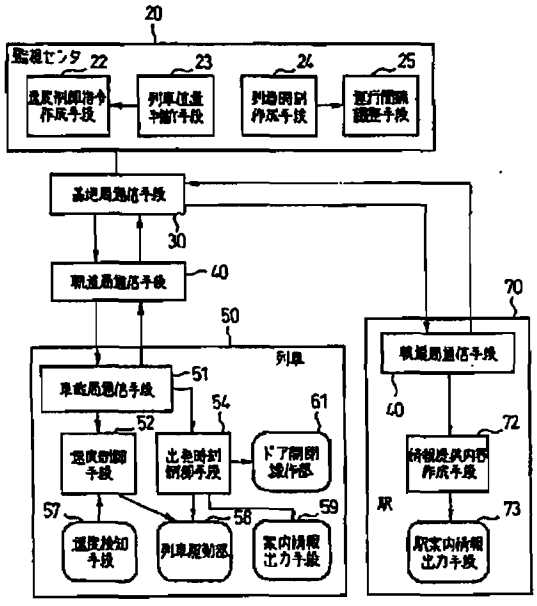
【図４】


20
監視センタ
22
23
24
速度制御指令作成手段
列車位置判断手段
到着時刻作成手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
速度制御手段
57
速度検知手段
58
列車制御部
70
軌道局通信手段
40
駅
72
情報提供内容作成手段
73
駅案内情報出力手段

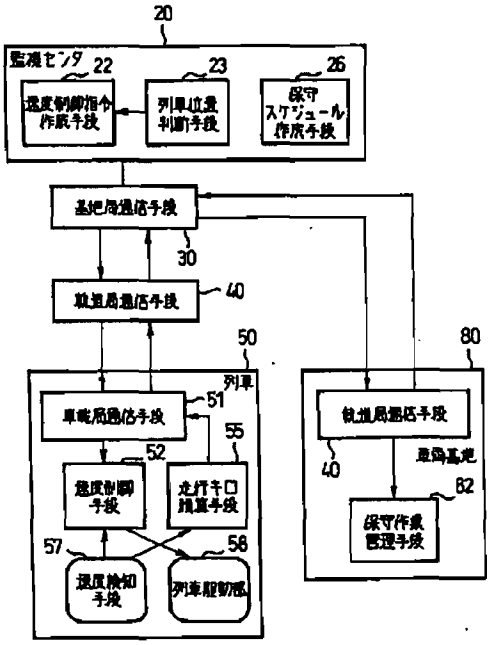
【図５】


20
監視センタ
22
23
24
27
速度制御指令作成手段
列車位置判断手段
到着時刻作成手段
営業管理手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
速度制御手段
56
乗車人数検知手段
57
速度検知手段
58
列車制御部
70
軌道局通信手段
40
駅
72
情報提供内容作成手段
73
駅案内情報出力手段

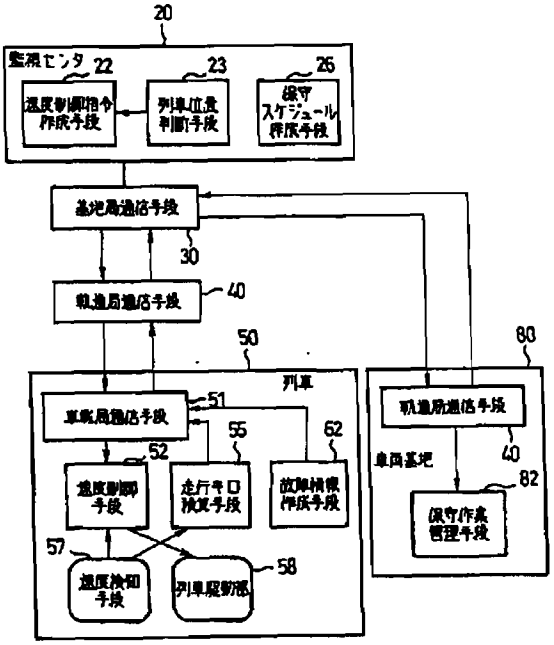
【図６】


20
監視センタ
22
23
24
25
速度制御指令作成手段
列車位置判断手段
到着時刻作成手段
運行情報調整手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
速度制御手段
54
止め時刻制御手段
61
ドア開閉操作部
57
速度検知手段
58
列車制御部
59
案内情報出力手段
70
軌道局通信手段
40
駅
72
情報提供内容作成手段
73
駅案内情報出力手段

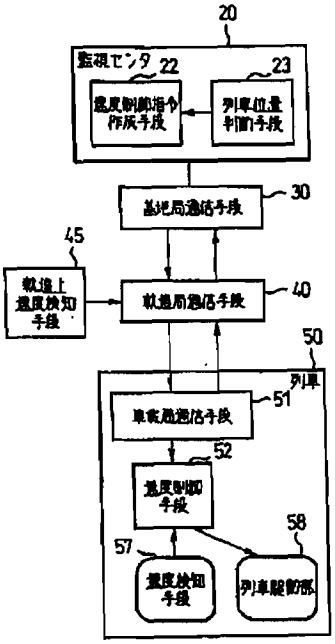
【図７】


20
監視センタ
22
23
26
速度制御指令作成手段
列車位置判断手段
保守スケジュール作成手段
基地局通信手段
30
軌道局通信手段
40
50
列車
車載局通信手段
51
52
速度制御手段
55
走行キロ積算手段
57
速度検知手段
58
列車制御部
80
軌道局通信手段
40
基準基地
82
保守作業管理手段

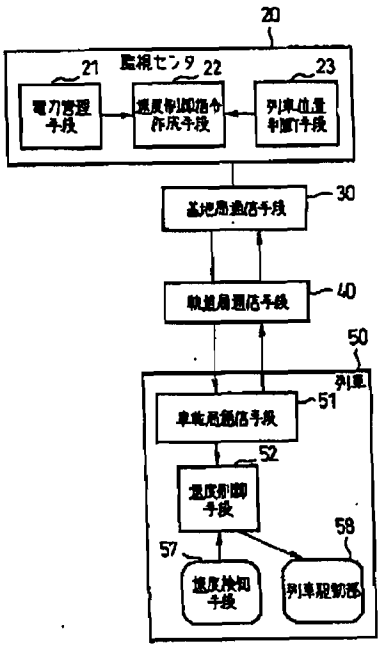
【図８】



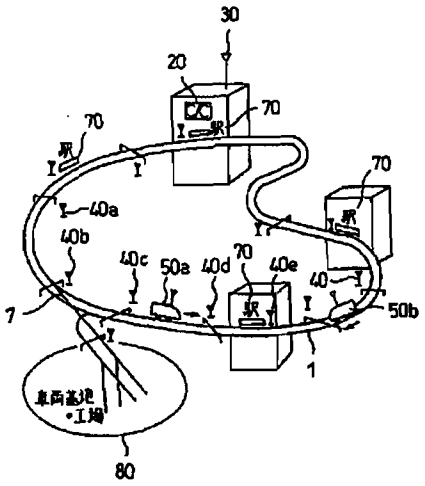
【図９】



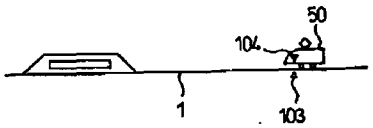
【図１０】



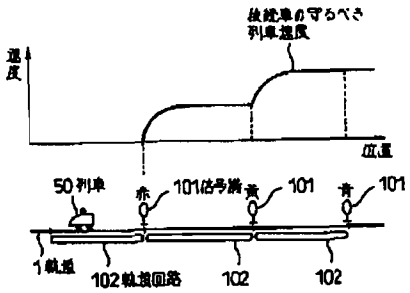
【図１１】



【図１３】



【図１２】


後続車の守るべき
列車速度
速度
位置
50 列車
赤
101 信号機
黄
101
青
101
1 軌道
102 軌道回路
102
102

4/9/2007

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 March 2001 (01.03.2001)

PCT

(10) International Publication Number
WO 01/015001 A2

(51) International Patent Classification[7]: G06F 17/00

(21) International Application Number: PCT/US00/23157

(22) International Filing Date: 23 August 2000 (23.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

09/378,939	23 August 1999 (23.08.1999)	US
09/378,940	23 August 1999 (23.08.1999)	US
09/410,553	1 October 1999 (01.10.1999)	US
60/201,243	1 May 2000 (01.05.2000)	US

(71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; 1 River Road, Schenectady, NY 12301 (US).

(72) Inventors; FERA, Gregory, John; 5664 Rockledge Drive, Erie, PA 16511 (US). BLILEY, Richard, Gerald; 1020 Belleview Drive, Erie, PA 15604 (US). GOMEZ, Ivan; 151 E. 4th Street, Erie, PA 16507 (US). PIERRO, Michael, James; 4717 Amherst Rd., Erie, PA 16506 (US). SCHLABACH, James, E.; 4185 Mountain Laurel Drive, Erie, PA 16510 (US). SCHNEIDER, William, Roy; 8990 Old Wattsburg Road, Erie, PA 16510 (US).

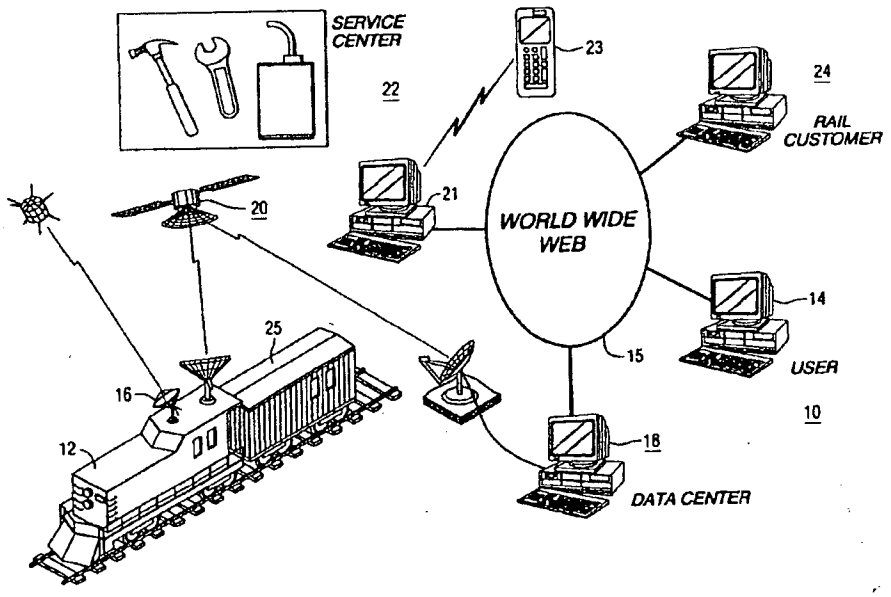
(74) Agent: MAIRE, David, G.; Holland & Knight LLP, P.O. Box 1526, Orlando, FL 32802-1526 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR MANAGING A FLEET OF MOBILE ASSETS



(57) Abstract: A method and apparatus for managing a fleet of mobile assets, such as locomotives (12), utilizing remote data transfer (36, 40), real time data monitoring (122), predictive failure analysis (132), and integrated work order processing (172). A global information network (15) is used to facilitate the communication and presentation of high volumes of data to various parties (14, 18, 22, 24) involved in the process.

WO 01/015001 A2

patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

(48) Date of publication of this corrected version:
12 September 2002

(15) Information about Correction:
see PCT Gazette No. 37/2002 of 12 September 2002, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 March 2001 (01.03.2001)

PCT

(10) International Publication Number
WO 01/015001 A3

(51) International Patent Classification[7]: G06F 17/60

(21) International Application Number: PCT/US00/23157

(22) International Filing Date: 23 August 2000 (23.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

09/378,939	23 August 1999 (23.08.1999)	US
09/378,940	23 August 1999 (23.08.1999)	US
09/410,553	1 October 1999 (01.10.1999)	US
60/201,243	1 May 2000 (01.05.2000)	US

(71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; 1 River Road, Schenectady, NY 12301 (US).

(72) Inventors: FERA, Gregory, John; 5664 Rockledge Drive, Erie, PA 16511 (US). BLILEY, Richard, Gerald; 1020 Belleview Drive, Erie, PA 15604 (US). GOMEZ, Ivan; 151 E. 4th Street, Erie, PA 16507 (US). PIERRO, Michael, James; 4717 Amherst Rd., Erie, PA 16506 (US). SCHLABACH, James, E.; 4185 Mountain Laurel Drive, Erie, PA 16510 (US). SCHNEIDER, William, Roy; 8990 Old Waltsburg Road, Erie, PA 16510 (US).

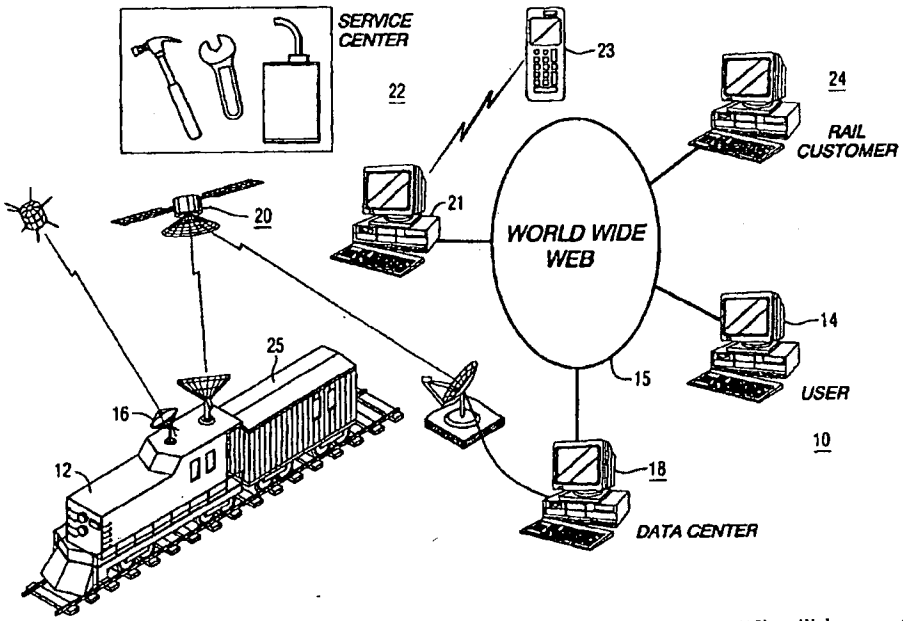
(74) Agent: MAIRE, David, G.; Holland & Knight LLP, P.O. Box 1526, Orlando, FL 32802-1526 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR MANAGING A FLEET OF MOBILE ASSETS



(57) Abstract: A method and apparatus for managing a fleet of mobile assets, such as locomotives (12), utilizing remote data transfer (36, 40), real time data monitoring (122), predictive failure analysis (132), and integrated work order processing (172). A global information network (15) is used to facilitate the communication and presentation of high volumes of data to various parties (14, 18, 22, 24) involved in the process.

WO 01/015001 A3

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
27 February 2003

(15) Information about Correction:
Previous Correction:
see PCT Gazette No. 37/2002 of 12 September 2002, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

APPARATUS AND METHOD FOR MANAGING A FLEET OF MOBILE ASSETS

The present invention relates generally to the field of managing a fleet of remote assets. In particular, the invention is described in the application of managing a fleet of locomotives.

BACKGROUND OF THE INVENTION

The management of a large fleet of mobile assets, such as a fleet of trucks, ships or railway locomotives, is a challenging logistical effort. There is continuing pressure for the owners of such assets to improve the efficiency of operations of the assets to remain competitive in the market place. For example, railroads must manage their fleets of locomotives to maximize the on-train time in order to remain competitive with alternative modes of transportation. The assignee of the present invention is a supplier of locomotive engines and has developed numerous design features and services to maximize the efficiency of operation of its locomotives. The assignee of the present invention has also undertaken to provide integrated maintenance services to the owners of locomotives. Such services include the operation of a repair and maintenance service center and the supply of necessary parts and labor. The coordination of the servicing of a large fleet of locomotives and the communication with the various parties involved in such efforts are monumental tasks.

United States patent 5,845,272 dated December 1, 1998, commonly owned with the present invention, describes a system and method for diagnosing failures in a locomotive. While such a system and method has proven beneficial, further improvements in fleet management are desired.

BRIEF SUMMARY OF THE INVENTION

Accordingly, a system and method are described herein for effectively integrating the diverse elements involved in the management of a fleet of mobile assets. The invention makes use of the data management powers of modern computer and global information networks by using such tools to collect, store, analyze, distribute and present information in a format and at a time when it can be used most effectively by people responsible for such assets.

The invention includes the aspects of real-time data collection from each of the mobile assets, computerized analysis of such data for failure detection and prediction, and the planning of maintenance activities responsive to such failure predictions prior to the asset being taken out of service. The planning of maintenance activities includes the selection of an optimal time and location for performing the work, with consideration given to the trends of the operating data, the availability of necessary repair resources, and other owner-defined criteria. Work planning further includes the automatic generation of appropriate work orders including the advance reservation of necessary service equipment, replacement parts and repair personnel. The various participants and stakeholders in these activities are provided with appropriate levels of information via a global information network. The information presentation power of the multi-media format of an Internet web site is ideally suited for accomplishing many of the communication functions necessary for implementing this invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention will become apparent from the following detailed description of the invention when read with the accompanying drawings in which:

FIG. 1 is a schematic illustration of a communications network for managing a fleet of mobile assets.

FIG. 2 illustrates the steps of a method for managing a fleet of mobile assets.

FIG. 3 is a block diagram of a system according to the invention for communicating data from a mobile asset.

FIG. 4 is a block diagram of the monitoring station apparatus of the system shown in FIG. 3.

FIG. 5 is a block diagram of a vehicle maintenance management method.

FIG. 6 is a block diagram of a system for conducting a remote inbound inspection of locomotives.

FIG. 7 illustrates an apparatus and method for generating work orders.

FIG. 8 illustrates a web page showing a route map for mobile assets.

FIG. 9 illustrates a web page showing the output of a search engine accessible via a global information network identifying the proximity of locomotives to a repair shop.

FIGs. 10-12 illustrate pages from a web site containing information related to the management of a fleet of locomotives.

DETAILED DESCRIPTION OF THE INVENTION

To effectively manage a fleet of mobile assets, it is necessary to avoid unexpected equipment failures and to accomplish maintenance and repair activities in a time efficient manner. There is a tremendous amount of information available related to a fleet of mobile assets. Such information may include design information, real time operating data, historical performance data including failure probabilities, parts inventories, and geographic information related to the assets, cargo being transported with the assets, parts, personnel and repair facilities, etc. Key to achieving efficient operation is the ability to communicate such information to people and places where it is needed, and to present the information in a format that makes it useful to accomplish the desired result.

Accordingly, the inventors have envisioned the system 10 of Figure 1 for use in managing a fleet of mobile assets. Although illustrated and described with respect to a fleet of locomotives 12, the invention may be implemented with other types of mobile assets, such as trucks, ships, etc. Furthermore, the apparatus and method described herein is useful for managing not only mobile vehicles but also the cargo transported with such vehicles. The communication system 10 allows a variety of different types of users to obtain detailed and timely information regarding each of the mobile assets 12. Such users may include the transportation company 14 who owns and operates the locomotives 12, a customer 24 of the transportation company, personnel in a locomotive service center 22, personnel in a data center 18, and the engineer on-board each individual locomotive 12. The locomotives 12 may be equipped with a plurality of sensors for monitoring a plurality of operating parameters representative of the condition of the locomotive 12 and of the efficiency of its operation. The locomotive 12 may also be equipped with a GPS receiver 16 or other satellite based or local instrument for determining the geographic location of the locomotive 12. Data regarding the location of the locomotive 12 and its operating parameters may be transferred periodically or in real time to a data base 18 by a data link 20, such as a satellite system, cell phone, optical or infrared system, hard-wired phone line, etc. The assignee of the present invention operates such a data center 18 at its Monitoring and Diagnostics Service Center (MDSC) in Erie, Pennsylvania. Affiliated with such a data center 18 may be one or more service centers 22 where the locomotives 12 are taken for repair and maintenance services.

As illustrated in Figure 1, the data center 18 and service center 22 may both be linked to a global information network, such as the Internet 15, by known types of data connections. Such links may typically be a computer interface through an internet service provider. The Internet and World Wide Web provide a means for communicating between the data center 18 and service center 22. Furthermore, these facilities may also be in communication with the transportation company user 14 via an Internet connection. Customers 24 of the transportation company or other members of the public may further be in communication with these facilities through

Internet links. Because the Internet 15 and known web page formats provide a means for communicating data and information in a multi-media format, such a global information network is a useful communication tool for displaying and communicating the large amount of data that may be associated with the operation of a fleet of mobile assets 12.

Figure 2 illustrates a method 28 for managing a fleet of mobile assets that may be implemented by using a communications system 10 as illustrated in Figure 1. Each mobile asset may be uniquely identified, such as by an identification number, as in step number 30 of Figure 2. One or more identifiers may also be associated with the cargo being transported with the mobile assets 12. For the embodiment of a fleet of locomotives 12, the operating parameters of each of the locomotives 12 may be monitored 32 by the on-board sensors. Preferably, such operating parameters are monitored in real time, and data related to these operating parameters is available for communication to a data center 18 wherever appropriate. The location of each asset is also determined 34, such as by using a GPS system or by otherwise identifying the locomotive to a particular location on the rail line. Data regarding both the location and the operating parameters for each locomotive 12 may be periodically downloaded 36 from an on-board data file to a centralized data base 39. In the event that a critical fault is identified 38 in one of the systems of a locomotive, it may be preferred to download data from the locomotive immediately 40 upon recognition of the fault. The timing of the download may also be determined based upon the availability and quality of the data link 20 between the locomotive 12 and the data center 18.

The database 39 located at the data center 18 may also include data representing inspection reports 42, maintenance records 44, and design information 46 related to the specific vehicles included in the plurality of mobile assets. For example, if a locomotive engine 12 is returned to a service center 22 for a periodic inspection and maintenance visit, information regarding the results of the inspection and maintenance activities may be used to update the database 39 for that particular locomotive 12. The database may also be updated 39 if the designer of the

locomotive 12 provides any revised design parameters 46, such as a new part number for an upgraded component. The quantity of data in such a data base may be immense when considering the number of vehicles in some fleets, and when considering the amount of data that may be collected on a periodic basis regarding the performance of each of the vehicles. However, the computing power of modern data processing equipment makes it easy to analyze 48 such a database. Various data processing routines may be used to generate performance reports 50 regarding each of the individual assets or the fleet as an entirety. Statistical data 52 may be calculated to aid in the analysis of the operating parameters of the fleet.

In order to effectively utilize the vast amount of data that may be available regarding a fleet of mobile assets, the output of the analysis 48 of such data must be effectively displayed and conveyed to an interested user 14. There may be more than one user 14,24 interested in the data, and the level of detail of interest may vary from time to time. The inventor has found that an Internet web page is an effective means for communicating such data and information. An Internet web page may be updated 56 to reflect the performance reports 50, operating statistics 52, and/or current location map 54 for the fleet of mobile assets. One or more such web pages may be utilized with appropriate hyperlinks to additional web pages. By nesting related web pages, the level of detail presented to the user 14 may be controlled by that user. For example, a location map 190 of FIG. 8 illustrating the current geographic location of each of the locomotives 12 owned by a transportation company may include a hyperlink 192 at the indication of the location of each of the locomotives 12. Such a map may also illustrate the location of service facilities. Similarly, for a fleet of trucks, a road map may be generated showing the location of each truck along with its route. By constructing such a map in a web site format, a hyperlink 192 may be provided on the map for each mobile asset to connect the user to an interconnected nested web page containing additional information regarding that particular vehicle. For example, while the location of the mobile asset may be seen on map 190, by double clicking a cursor on the symbol for a single locomotive 12, the speed, destination, route, cargo information, fuel level, crew information, and other

operating information for that locomotive may be viewed on nested web pages. One user, such as a customer 24 of the transportation company, may only be interested in the location of the train. Another user 14, such as a service engineer employed by the railroad, may be interested not only in the location of the locomotive but also in the amount of fuel on board or other operating parameter. Both such users 14,24 can quickly obtain the information they need by a simple point and click operation using known Internet browser technology.

Known search engine software technology may be provided 70 to allow a user to identify desired information related to the mobile assets 12 via the global information network 15. Access to an appropriate web page containing the desired information may then be provided via hyperlink directly from the search engine.

An Internet web page display used with the present invention may incorporate the full power of the multi-media capabilities of a global information network 15. For example, the location map 54 may include the use of color to indicate a readiness status for each locomotive, for example, green for a properly functioning locomotive, yellow for a locomotive exhibiting an anomaly in one of its operating parameters, and red for a locomotive having a critical fault. The user 14 of such information would be able to quickly assimilate a large volume of data and to have his/her attention directed to important portions of the data. Such a web page may also include links to additional pages containing drawings of component parts, specifications, or operating and repair manuals or other design parameters 46. In some instances, it may be advantageous to include video information on such a web site, such as still or motion video produced by the operator of the locomotive and transmitted directly from the mobile asset to show the condition of a component. Such video information may be accompanied by live audio information, including speech from the operator, thereby allowing the user 14, the operator located on the locomotive 12, and personnel at a service center 22 to conference regarding a developing anomaly. Communication over the global information network 15 using Internet Protocol allows packets of data to be communicated between different kinds

of networks. The packets may consist of voice, text, video, audio or other types of data. The system 10 of Figure 1 is adaptable to make use of future platforms as they become available.

When a critical fault is identified 38, or an anomaly is found to exist 58 in one or more of the operating parameters, a service recommendation may be developed 60. Information regarding the anomaly 58, critical fault 38, and/or service recommendation 60 may also be uploaded 56 to an Internet web page. When appropriate, a user may be notified 62 that new or urgent information has been displayed on the Internet web page. The user may be notified 62 by an electronic mail message, telephone call, fax or other simple form of communication. The user may then actively interact 68 with the web pages that present data regarding the mobile asset of interest. Such interaction may include a request by the user for additional information. Such a request would be transmitted to the locomotive operator or other appropriate person via the global information network connection, and the response would be communicated in return.

The information available to the user on the Internet web page may also include information regarding services that are available 64 and/or a parts inventory 66 that may be important to any decision regarding a maintenance recommendation 60. Personnel located at a service center 22 may not only provide data for the user 14, but may also receive a communication from the user 14 regarding a planned maintenance activity, thereby facilitating the scheduling of maintenance activities at the service center 22.

The advantage of the communication system 10 of Figure 1 and method 28 of Figure 2 may be appreciated by considering a three locomotive train 12 operating in a relatively flat terrain on its way to a mountainous section of a rail line. Because the three locomotives are operating at reduced capacity along the flat terrain, the operator of the locomotives who may be physically sitting in the front locomotive may not be aware that a degraded condition has developed in the third locomotive. For example, a degraded cooling system may cause the third locomotive to throttle back to a reduced power output. Because the first and second locomotives are able to

provide the necessary power, the progress of the train is unimpeded. Should this degraded condition continue to go unnoticed, the train would be unable to negotiate the mountainous terrain that it is approaching later in the journey. However, on-board sensors on the third locomotive identify the degraded cooling condition and data related to the degraded condition is immediately downloaded 40 to the data center 18 to update the data center database 38. Computers and/or personnel located at the data center 18 may analyze the data 48 and identify that the anomaly exists 58 and determine that a maintenance action 60 is recommended. For example, if a fan motor controller has developed a malfunction, a maintenance recommendation 60 to replace the control panel may be generated. A web page display showing the location of the locomotive would then be promptly updated 56 to show the degraded condition, and the railroad maintenance personnel are notified 62 by an electronic mail message that is automatically generated at the data center 18. The e-mail will include a Universal Resource Locator (URL) directing the maintenance personnel to an Internet web page containing information regarding the degraded condition and the recommended maintenance activity. The maintenance personnel then view the available parts inventory 66 illustrated on another web page to verify the availability of the required control panel in a service center 22 located along the route of the locomotive 12. In this example, a user 14 is able to utilize the power of a global information network 15 web page presentation to quickly assess the importance of anomaly affecting one of a fleet of mobile assets and to assess various options for addressing such anomaly. For this example, the degraded locomotive may be repaired prior to the train becoming stalled on a mountainous section of the track, thereby avoiding a large out-of-pocket expense and a costly schedule delay for the transportation company. The speed of communication via the Internet and the breath of information that may be effectively communicated via an Internet web page make the communication system 10 of Figure 1 and the method of managing assets 28 of Figure 2 beneficial for a large fleet of mobile assets distributed over a large geographic area.

Access to an Internet web page containing important information regarding a fleet of mobile assets may be restricted to only those users having appropriate authorization to access such data. For example, information derived from the analysis 48 of the data base may be displayed on a password protected Internet web page. Only authorized users 14,24 would then be provided with the password necessary to gain access to the web page. Similarly, information received from a user and used to update the web page 56 may only be accepted as authentic if the user enters an appropriate password to confirm his/her identity. Other protection measures such as encrypting data may also be used. In some cases it may be desired to have at least a portion of the information displayed on an Internet web page be made publicly available. For example, it may be desirable to make the location map 54 for at least a portion of the mobile assets available for public viewing. In the case of a railroad transportation company, the location of passenger trains may be information that can be made available on a public Internet web page, whereas the location of freight trains may be limited to only specific industrial customers of the railroad company.

The present invention may further include a capability for predicting vehicle failure and for using such predictions to plan repair and maintenance work for each individual asset. One data is collected from the mobile assets, it may be used to develop a variety of types of information regarding the mobile assets. Such a capability includes monitoring on-board systems parameter data transmitted from each vehicle as it is operating; determining whether any of the monitored data is out of a predetermined range; calculating trends for monitored data determined to be out of range; identifying any system fault; predicting when such system is likely to fail unless corrected; and predicting which, if any, system must be corrected to avoid vehicle failure, developing a service recommendation, and communicating the service recommendation via a global information network. An apparatus to accomplish such steps is generally identified by numeral 110 of Figure 3, and it comprises a communication element(s) 112 and a monitoring station 114. Communication element(s) 112 are carried by the remote vehicle, for example locomotive 12. The communication element(s) may comprise a cellular modem, a satellite transmitter or

similar well-known means or methods for conveying wireless signals over long distances. Signals transmitted by communication element 112 are received by monitoring station 114 that, for example, may be the maintenance facility 22 or data center 18 of Figure 1. Monitoring station 114 includes appropriate hardware and software for receiving and processing vehicle system parameter data signals generated by locomotive 12 from a remote location. Such equipment, as illustrated in block diagram form in FIG. 4, comprises receiving element 116, processing element 118, and man-machine interface element 120.

Examples of suitable receiving element 116 include a satellite communications receiver or cellular communications receiver. Processing element 118 may comprise a processor, memory and modem or Integrated Services Digital Network (ISDN) adapter of a conventional personal computer or workstation coupled with software capable of executing the functions represented in FIG. 4. Suitable processing element 118 may include a locomotive failure diagnostic system as described in U.S. Patent No. 5,845,272. Man-machine interface element 120 may include a monitor, keyboard, mouse, printer and/or other related I/O devices for enabling interaction between a human operator and processing means 118. Monitored vehicle parameter data received by receiving means 116 is communicated to processing element 118 wherein it is processed in the manner shown in FIG. 5.

Many vehicle system operating parameters are monitored, and trends are calculated on a subset of those parameters, or on all of the parameters. Among the parameters which may be monitored for locomotives are ambient air temperature, train notch, total track and force power, total voltage, total amps, software versions, engine RPM, engine temperature, crankcase pressure, dynamic braking, battery voltage, and voltage and amperage for all auxiliary motors. For other vehicles, other sets of parameters may be monitored. For a turbo-charged diesel truck, for example, monitored parameters may further include vacuum, fuel injection pressure, intake boost pressure, throttle position, etc. The monitored parameters may also include measurements of data important to the cargo 25 being transported by the mobile asset, for example the temperature in a refrigerated railcar or highway trailer.

Referring to FIG. 5, there is shown a block diagram of the operations performed by processing element 118 upon receipt of vehicle systems parameter data transmitted by communication element 112. Upon issuance of a transmission request from monitoring station 114, communication element 112 preferably continuously transmits the data and receiving element 116 preferably continuously receives the data. Using receiving element 116, processing element 118 monitors the data as indicated at 122. A first determination 124 made by processing element 118 is whether any of the data is outside of an acceptable range for any of the vehicle systems being monitored. If the processing element identifies out-of-range data, it executes a routine 126 to calculate whether the data suggests one or more trends suggestive of possible or actual impairment or failure of the vehicle systems being monitored.

The trends are calculated by comparing values for a given parameter over a period of time and comparing those values with historical data for identical vehicle systems. This enables rapid and accurate correlation of trending data with a dedicated fault occurrence experience database. The trends are preferably calculated based in part on prior downloads collected in the database. The database is preferably continually updated and may be stored in the memory of processing element 118, elsewhere at the monitoring station 114, or off-site whereby it may be accessed on-line.

An example of a trend that may indicate a system fault would be a crankcase overpressure trend from negative to positive. Such a condition may be suggestive of a cylinder or piston problem or excessive engine wear. Processing element 118 is preferably capable of linking the results of several observed trends to more precisely diagnose a problem. For instance, the aforementioned crankcase overpressure trend may be coupled by processing element 118 with an observed trend in electronic fuel injection parameters to more clearly determine the cause of the problem.

Once an unfavorable trend is detected, it is identified by processing element 118 with a stored fault code as indicated at 128. Fault codes corresponding to a wide variety of faults may be stored, and trends may be calculated for some or all of them. Examples of faults that may be categorized include, without limitation, overcurrents, flashovers, crankcase overtemperatures, crankcase overpressures, communication failures, electrical ground failures, air conditioner converter failures, propulsion system faults, auxiliary system faults, propulsion motor faults, auxiliary motor faults, auxiliary system charging faults, engine cooling system faults, oil system faults, control wiring faults, and microelectronics faults.

As indicated at 130, following identification and categorization of a fault, processing element 118 then prioritizes the fault. The fault prioritization process involves comparing the identified fault code with a historical fault database whereby the fault may be classified as critical, restrictive, or both critical and restrictive. A critical fault is one that will cause imminent vehicle shutdown if not immediately corrected. Examples include, without limitation, serious engine problems, main and auxiliary alternator grounds, coolant or oil pressure loss and microelectronics failures. A restrictive fault is one that, although not likely to cause imminent vehicle shutdown, impedes vehicle performance. A restrictive fault is likely to become progressively worse and may degenerate into a critical fault if not timely addressed. Examples of restrictive faults include, without limitation, an overheated engine or the loss of one or more traction motors, each of which deplete horsepower and may cause other strain on the engine or other systems of the vehicle.

After a fault has been prioritized, processing element 118, as indicated at 132, predicts which vehicle system is likely to fail. Additionally, processing element also predicts the estimated time of failure, preferably expressed as an approximation of the distance (in miles or kilometers, for example) the vehicle can be safely operated before it must be shopped prior to failure or the amount of operating time prior to failure. The optimum time the vehicle should be shopped is determined by resorting to the relevant trend data for the identified fault and comparing that data

with a projected time-of-failure knowledge base which has been inputted into the database for the calculation.

As indicated at 134, processing element 118 is also preferably programmed to instruct a human operator at monitoring station 114: (1) whether to correct the fault prior to scheduled maintenance of the vehicle, (2) when to correct the fault, (3) what fault to correct (preferably including what parts or components of the vehicle to repair), and (4) the optimal facility at which to correct the fault. The optimal repair facility is dependent upon the proximity of the vehicle to a facility and whether the facility has the capability, including parts, service equipment and personnel expertise necessary to repair the fault. Personnel at the service center are alerted to the planned arrival of the locomotive at step 135.

The data monitored at step 122 may include data regarding the cargo 25 being transported by a mobile asset 16. Such data may be used to develop information regarding the cargo, and such information may be distributed via the global information network 15. A web site may be developed including information of interest to the owners of the cargo 25, such as the location of the cargo, and such owners may be provided access to the respective web pages via secured or unsecured web access via the global information network 25. A route map such as is illustrated in FIG 8 may be posted on the global information network 15 to illustrate the location of various cargo loads. Two-way communication may be provided between a controller 24 for the operation of the mobile assets 16 and the owners 14 of the cargo 25.

The apparatus and method of the present invention may also include improvements in the processing of a mobile asset through the repair facility 22 of FIG. 1 when maintenance/repairs are necessary. FIG. 6 illustrates in block diagram form a system for performing an inspection of a remote inbound vehicle, and for planning the maintenance/repair activities on that vehicle before it arrives at a service location. Such a process begins by identifying an inbound mobile asset, such as a locomotive 12, and its scheduled maintenance date 141. The maintenance schedule may be maintained on a computer in the service center 22 or at any other convenient

location accessible through the global information network 15 of FIG. 1. Prior to arrival at the shop, a signal is sent to the communication element 112 of FIG. 3, such as an on-board computer, and instructs it to transmit data on all monitored parameters 142. The service personnel and service center computer have access to a vast amount of historical and experiential data pertaining to the systems used in various locomotive models, and they use such data according to an algorithm to determine which maintenance and repair operations are required, advisable, and optional 143 for the particular inbound locomotive. A report is generated and sent to the owner of the asset, such as via an Internet web page, to identify such operations while the vehicle is still inbound. Decisions 144 are made as to which of the advisable and optional maintenance operations will be performed when the locomotive arrives at the shop. Maintenance personnel may then begin preparations for the repair activities 145 prior to the mobile asset arriving at the repair facility. The system envisions beginning repair operations 146 immediately upon arrival of the asset 12 at the service location 22, obviating the requirement of a time-consuming inspection and decision-making process after arrival in the shop. Information regarding the status of a service activity may also be distributed via the global information network.15. Once a repair is completed and the locomotive is returned to service, performance data may again be monitored 147 to conform a satisfactory completion of the service activity, and information regarding the satisfactory completion may be distributed via the global information network.

The step 143 of determining which operations are recommended may include the analysis process illustrated in FIG. 5. Trends are calculated 126 by comparing values for a given parameter over a period of time and comparing those values with historical data for identical vehicle systems. This enables rapid and accurate correlation of trending data with a dedicated fault occurrence experience database. The trends are preferably calculated based in part on prior operating data that has been downloaded and collected in the database. The database is preferably continually updated and may be stored in the memory of the shop computer or off-site at data center 18 where it may be accessed on-line via the network 15 of FIG. 1.

The present invention enables service personnel to reliably and quickly retrieve a vast amount of archived information directly onto the job floor, either via a kiosk 21 located within the service facility 22 and/or with portable hand-held communication and display units 23 that the service personnel can take with them right to the locomotive 12. Such data portals 21,23 may communicate to a central computer via electromagnetic signals, such as RF signals, or on-line via the Internet or via an intranet of the service provider. The data portals advantageously display the information directly at the work site location. It will be appreciated that the present invention contemplates the use of mobile wireless, web-access devices that could directly access the intranet of the service provider.

Electronic Service Delivery (E-izing) as contemplated by the present invention is a broad term used to describe the result of many applications to be utilized at a service application site 22. It involves streamlining and standardizing multiple servicing processes, as well as providing the users with all the information they need to maintain and repair a product on location. A first data portal may be a kiosk 21, e.g., a PC-based information stand that contains all the technical and safety information that is currently available in hard copy. Information is made conveniently available at the click of mouse, the touch of a screen, a voice command, etc. A second portal may be a handheld device 23 that could utilize the kiosk 21 as its hub and may be used for displaying real time information relevant to the tasks involved in inspecting and repairing the product 12. The present invention may further enable the display of service-related information on a monitoring board to allow service personnel to quickly and accurately know on a real time basis the status of every piece of equipment being serviced at the service site 22 or at other sites. By way of example, the information transmitted through each of these portals 21,23 may be technical information available in hard copy but enhanced through suitable multimedia applications, such as audio and/or visual drill downs, and/or wizard applications that empower the service personnel to make uniformly correct decision across all the service sites.

The electronic data delivery system of the present invention allows for improving field service operations by applying e-Business technologies to replace manual paper based processes. The business benefit will include improved availability of the asset by reducing the cycle time of the repairs and to have higher quality repairs. In addition, other processes, such as inventory management, will be improved to have the correct part available when needed.

As shown in FIG. 7, a work order flow module 150 is used to control the various repair processes. One exemplary step or action is to develop an accurate work scope 152 in response to a service recommendation, such as is developed at step 143 of FIG 6. Information will be electronically accumulated to develop the work scope, and at least part of this information may be communicated via the global information network 15 as illustrated in FIG 1. By way of example and not of limitation, the information may include the following: performance information from the product 154, repair history information 156, information from the customer 158, required and optional repairs 160, and information learned during inspection 162.

The next step is to use the work scope to determine the sequence of repairs 164 based on customer need 158, materials availability 166, and resource availability 168, and drawing upon customized or standard work steps stored in a data warehouse 169. The process will provide service personnel with the information needed to determine the order of repairs and to communicate to the craft workforce.

The execution of the repairs will take place 170 by directing the worker via the data portal 21,23. The work order 172 provided to the worker via the data portal will direct the worker through each repair that is needed. The completion of each step is recorded via the data portal to update the data warehouse 169 and to provide real-time repair status information via a monitoring board 174. A feedback loop will be used to update the current production configuration. The work order 172 will provide a more controlled and accurate repair process.

The information obtained from the work order completions will allow for monitoring the status of the repairs and will also allow customers 176 to get real-time status of their product in the repair cycle. The data will also be used to improve

reliability of the product and to compare and improve field shop processes across field sites. Communication of such information can be efficiently accomplished via the global information network 15 of FIG. 1.

In operation, consider a scenario of how the present invention improves productivity and performance in a plurality of locomotive fleets by leveraging advanced communication, diagnostic, scheduling, data handling and locomotive repair technologies, thereby increasing train on time and up time. Envision a train operating along a rail route. Diagnostic modules are regularly monitoring the various subsystems of the locomotive to ensure operations stay within set parameters. For example, the onboard system may be configured to maintain optimal fluid conditions to maximize oil life without sacrificing either engine reliability or locomotive performance. If the onboard monitor recognizes trends outside predefined limits, the fluids management system highlights the abnormality on the locomotive indicating a potential concern. Based on the severity of the concern, the system may automatically call the remote diagnostics service center with the necessary data to confirm the diagnosis. Expert systems and/or expert personnel evaluate whether a faulty condition is developing outside of the normal boundaries and a corrective action may be proposed and communicated via a global information network. The recommended action may be supplied directly into the train control system. At this time, the data center or service personnel may evaluate the most logical repair location in terms of various criteria, such as train proximity, parts, repair equipment availability, manpower availability, etc. The service recommendation automatically triggers the creation of an electronic work order 172 within a service shop management system. A notification is then sent, such as via an e-mail message or by providing information on an Internet web page, to the service team detailing the parts and labor necessary for a timely and accurate repair.

The recommendation also sets a proximity trigger to notify the service shop when the locomotive is within a certain distance of the repair location. As soon as the service team receives information about the necessary repair, team members gather or reserve the parts, equipment and personnel needed to perform the corrective

action 145. The approaching locomotive may automatically forward a notification message to the service repair shop indicating that it is approaching. Alternatively, the service personnel may utilize a search engine 70 to identify the proximity of locomotives to their respective service shop. An example of a web page presenting such information is shown in FIG 9. A hyperlink may be provided on this screen to connect the user with nested web pages showing more detailed information regarding a particular locomotive. Upon arrival of the train to the scheduled repair station, the locomotive is repaired by a service technician equipped with the necessary parts and the wireless handheld device 23 that contains the appropriate maintenance, safety and training instructions for the repair to be accomplished safely, quickly and accurately. Furthermore, plans may be made in advance of the train arriving at the service shop for the continued transportation of the cargo being transported by the train, thereby avoiding excessive delays in cargo delivery.

The service technician informs the service shop management system that the operation has been completed. The train continues on its route without delay. During its journey, the technology service center monitors the latest downloaded data 147 to ensure the problem has been corrected.

The global information network 15 facilitates the effective communication of many forms of information for improving the management of a plurality of mobile assets 12. A web site accessible through the global information network 15 and using standard Internet Protocol can present information in a variety of formats to satisfy the unique requirements of a variety of users. Such information may include failure predictions, service recommendations, the availability of service shops 22, parts and personnel, the location of a mobile asset 12 or its cargo 25, performance data, audio and video information produced on-board the mobile asset, two-way communication between a mobile asset 12 and a fixed location 14,18,22,24, statistical information regarding the availability of the assets 12, repair status information, etc. Web site technology, including interconnected web pages and hyperlink connectivity, may be used to present multi-media information. Example web pages from a web site created as part of the system 10 of Figure 1 are illustrated

in Figures 10-13. Figure 10 illustrates a web page 200 providing hyperlinks to a variety of design documents for a locomotive. One such hyperlink 202 takes the user to an interconnected page having a specific troubleshooting guide. That page is illustrated in Figure 11. Web page 200 also includes the capability for the user to conduct a search, such as by inputting a specific vehicle number 204. Figure 12 illustrates another web page 210 whereby best practices are shared by the posting of messages by various users. Here, again, various search capabilities are provided 212 to enable the user to use the information effectively, and various hyperlinks 214 provide easy connections to other associated web pages and functions. As bandwidth capabilities increase and become less expensive, the benefits of the disclosed invention will become even more important.

CLAIMS

What is claimed is:

1. A method for managing a fleet of mobile assets, the method comprising:

transferring data representing operating parameters from each of a plurality of mobile assets to a database

monitoring the data to identify at least one of the operating parameters for one of the mobile assets that is outside a predetermined range of values; and

predicting a failure in the one of mobile assets based upon a trend in the at least one of the operating parameters.

2. The method of claim 1, further comprising:

identifying a repair activity responsive to the at least one of the operating parameters;

selecting a repair location and schedule for the repair activity responsive to the predicted failure and the location of the one of the mobile assets.

3. The method of claim 1, further comprising:

alerting personnel at the selected repair location of the schedule for the repair activity;

developing a work scope of maintenance activities including the repair activity;

generating a work order containing information necessary to accomplish the work scope prior to the one of the mobile assets arriving at the repair location.

4. The method of claim 1, further comprising posting information related to the predicted failure on a global information network web page.

5. A method for providing service to a mobile asset, the method comprising:

scheduling a first maintenance activity to be conducted on a mobile asset at a service location;

prior to the mobile asset arriving at the service location, downloading data representative of operating parameters for the mobile asset to a database;

comparing the downloaded data to other data stored on the database to identify a second maintenance activity to be conducted on the mobile asset at the service location;

preparing for the first and the second maintenance activities prior to the mobile asset arriving at the service location; and

conducting the first and the second maintenance activities on the mobile asset at the service location.

6. The method of claim 5, further comprising:

analyzing the downloaded data to identify an operating parameter outside a predetermined range;

evaluating a trend in the operating parameter outside a predetermined range to predict a failure in the mobile asset;

identifying the second maintenance activity in response to the predicted failure.

7. The method of claim 5, wherein the step of preparing further comprises:

developing a work scope to be conducted on the mobile asset at the service location; and

preparing a work order containing information necessary to conduct the work scope.

8. The method of claim 5, further comprising posting information related to the first and the second maintenance activities on a global information network web page.

9. A method for managing a fleet of mobile assets, the method comprising:

downloading diagnostic data from each of a plurality of mobile assets to a database;

analyzing the diagnostic data to recommend a service activity for one of the mobile assets;

scheduling the one of the mobile assets to be serviced at a service location;

generating an electronic work order at the service location responsive to the service activity prior to the one of the mobile assets arriving at the service location;

executing the service activity in accordance with the work order.

10. The method of claim 9, further comprising providing information related to the service activity to a user via a global information network web page.

11. The method of claim 9, further comprising issuing a proximity notification to the service location indicative of the proximity of the one of the mobile assets to the service location.

12. An apparatus for providing maintenance services to a fleet of mobile assets, the apparatus comprising:

a database;

a communication element associated with each of a plurality of mobile assets for communicating data associated with a plurality of operating parameters for each asset to the database;

a processing element for manipulating data in the database to identify a service activity for one of the mobile assets;

a work order module associated with the processing element adapted to produce a work order containing information related to the service activity.

13. The apparatus of claim 12, further comprising a data link to a global information network for presenting information related to the service activity on a web page.

14. A method for managing a fleet of mobile assets, the method comprising:

providing a data base;

monitoring a plurality of operating parameters for each of a plurality of mobile assets;

transferring data regarding operating parameters for each asset to the data base;

posting information derived from the data base on an Internet web page.

15. The method of claim 14, further comprising:

determining the location of each asset;

transferring data regarding location for each asset to the data base; and

posting a graphical display of the locations of the assets on an Internet web page.

16. The method of claim 14, further comprising:

storing maintenance records for each asset in the data base;

analyzing the maintenance records and the operating parameters to develop a maintenance recommendation for each asset;

displaying data related to the maintenance recommendations on an Internet web page.

17. The method of claim 16, further comprising the steps of:

storing data related to a parts inventory in the database;

analyzing the data related to the maintenance recommendations and the parts inventory to generate a parts order list;

displaying data related to the parts order list on an Internet web page.

18. The method of claim 14, further comprising:

monitoring the operating parameters to identify an anomaly in the operating parameters of a first of the assets;

developing a maintenance recommendation for the first of the assets in response to the anomaly; and

posting the maintenance recommendation on an Internet web page.

19. The method of claim 14, further comprising the steps of:

monitoring the operating parameters to identify a critical fault in a first of the assets;

transferring data related to the critical fault from the first of the assets to the data base; and

displaying information related to the critical fault on an Internet web page.

20. An apparatus for managing a fleet of mobile assets, the apparatus comprising:

a database;

a communication element associated with each of a plurality of mobile assets for communicating data associated with a plurality of operating parameters for each asset to the database;

a processing element for manipulating data in the database to predict a failure in one of the mobile assets; and

a data link in communication with a global information network for posting information related to the plurality of mobile assets on a web page.

21. A method for managing a plurality of mobile assets, the method comprising:

collecting data regarding each of a plurality of mobile assets;

using the data to develop information regarding each mobile asset; and

distributing the information via a global information network.

22. The method of claim 21, further comprising:

analyzing the data to identify an operating parameter that is outside a predetermined range for one of the plurality of mobile assets;

developing a service recommendation in response to the identified operating parameter; and

communicating the service recommendation via the global information network.

23. The method of claim 22, further comprising:

developing a work order responsive to the service recommendation; and

communicating the work order via the global information network.

24. The method of claim 21, further comprising communicating the information via a web site comprising a plurality of interconnected web pages accessible via the global information network.

25. The method of claim 24, further comprising:

posting a first portion of the information related to each one of the mobile assets on a respective web page; and

providing a hyperlink on each respective web page to a respective nested page containing a second portion of the information related to the respective one of the mobile assets.

26. The method of claim 24, further comprising:

providing a search engine for identifying desired information related to the mobile assets via the global information network; and

providing access via a hyperlink from the search engine to at least one of the plurality of interconnected web pages containing the desired information.

27. The method of claim 21, wherein the step of distributing information further comprises:

linking a data center to the global information network;

linking a service center for the mobile assets to the global information network; and

posting a recommendation for a service activity for one of the plurality of mobile assets on a web site accessible via the global information network.

28. The method of claim 27, further comprising posting information regarding the status of the service activity on the web site.

29. The method of claim 22, further comprising:

undertaking a service activity on the one of the plurality of mobile assets; and

distributing information regarding the status of the service activity via the global information network.

30. The method of claim 29, further comprising posting one of the group of audio information and video information related to the status of the service activity on the web site.

31. The method of claim 29, further comprising:

collecting additional data regarding the operation of the one of the plurality of mobile assets following the completion of the service activity;

analyzing the additional data to confirm a satisfactory completion of the service activity; and

distributing information regarding the satisfactory completion of the service activity via the global information network.

32. The method of claim 21, further comprising:

collecting data regarding cargo being transported by the respective mobile assets;

using the data regarding cargo to develop information regarding the cargo; and

distributing the information regarding cargo via the global information network.

33. The method of claim 32, further comprising:

developing a web site including a respective web page containing information regarding the cargo owned by each one of a respective plurality of customers; and

providing access to the respective web pages via the global information network to the respective plurality of customers.

34. The method of claim 33, further comprising providing two way communication between a controller for the plurality of mobile assets and the respective plurality of customers via the global information network.

35. The method of claim 32, wherein the information regarding the cargo comprises the location of the cargo; and

further comprising providing a route map for the plurality of mobile assets including the location of the cargo via the global information network.

36. The method of claim 21, further comprising:

using the data to develop information related to the operational status of each of the plurality of mobile assets;

developing a web site containing the operational status information; and

providing access to the web site via the global information network.

37. The method of claim 21, further comprising providing two way communication between personnel located at a fixed location and personnel located on the plurality of mobile assets via the global information network.

38. The method of claim 21, further comprising;

using the data to develop a failure prediction for at least one of the plurality of mobile vehicles; and

including information related to the failure prediction on a web site accessible via the global information network.

39. The method of claim 38, further comprising providing information related to the availability of a service facility on the web site.

40. The method of claim 21, wherein the step of distributing the information further comprises:

developing a web site presenting the information in the form of at least one of the group of video information and audio information; and

providing access to the web site via the global information network.

41. The method of claim 40, further comprising developing the web site to include one of the group of video information produced on-board one of the plurality of mobile assets and audio information produced on-board one of the plurality of mobile assets.

42. The method of claim 21, further comprising:

using the data to develop statistical information regarding the availability of the plurality of mobile assets;

developing a web site to display the statistical information on a plurality of interconnected web pages;

providing access to the web site via the global information network.

43. The method of claim 42, further comprising:

using the data to develop information regarding repair activities on the plurality of mobile assets; and

including the information regarding repair activities on the web site.

44. An apparatus for managing a fleet of vehicles, the apparatus comprising:

a data collection element associated with each of the vehicles for obtaining data related to the operation of the respective vehicle;

a data storage element in communication with the data collection element for storing the data;

a processing element in communication with the data storage element for manipulating the data; and

a global information network linking the data collection element, data storage element and processing element.

45. The apparatus of claim 44, further comprising:

the processing element further comprising a failure prediction element for predicting a failure in at least one of the vehicles and posting a service recommendation for the at least one of the vehicles responsive to a failure prediction on a web page accessible via the global information network; and

a service facility having the capability for implementing the service recommendation and having a link to the global information network.

46. The apparatus of claim 44, further comprising a route map comprising a web page accessible via the global information network and in communication with the processing element for depicting information regarding the vehicles.

47. The apparatus of claim 44, further comprising a web page accessible via the global information network and in communication with the processing element for depicting information regarding the vehicles.

SUBSTITUTE SHEET (RULE 26)

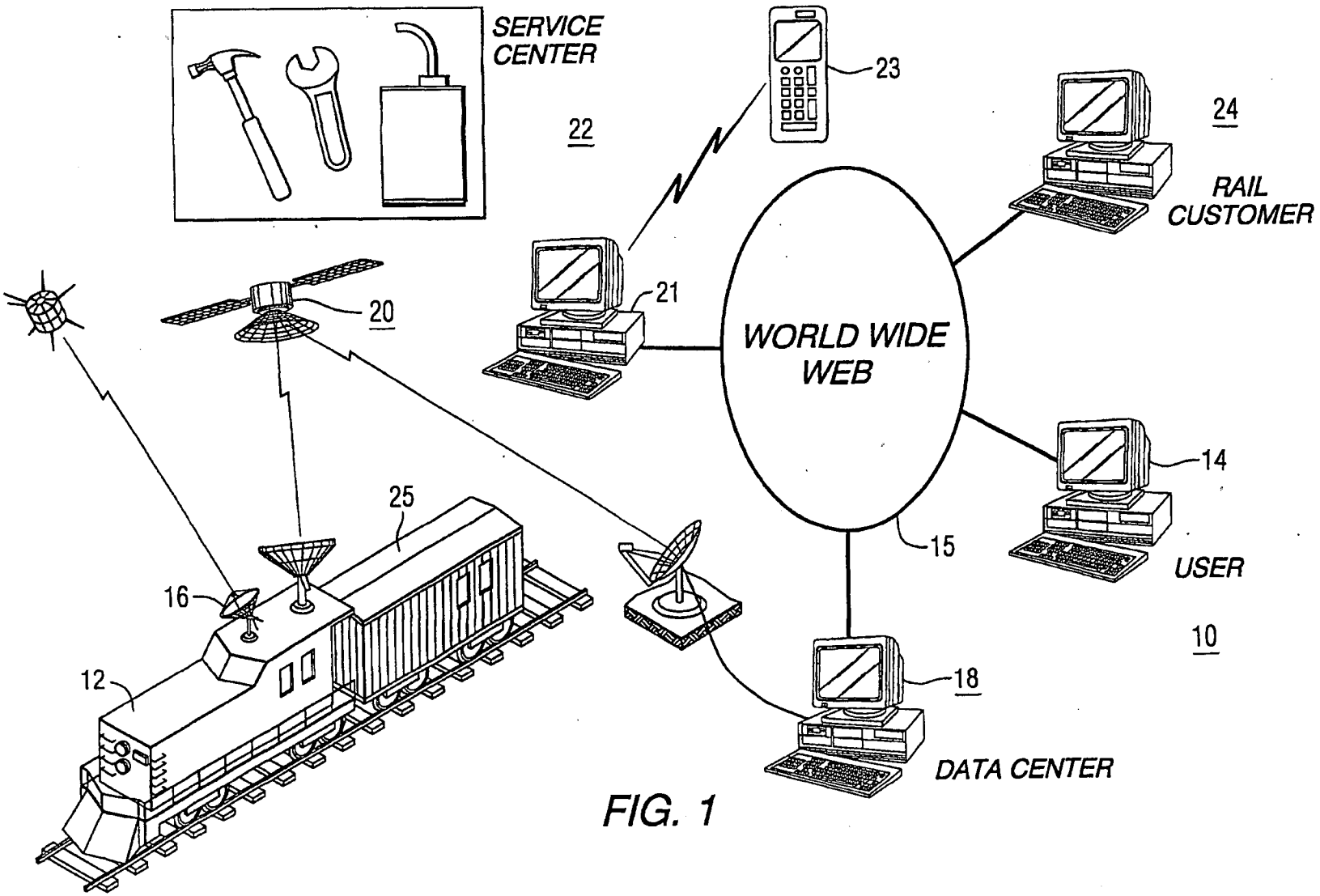


FIG. 1

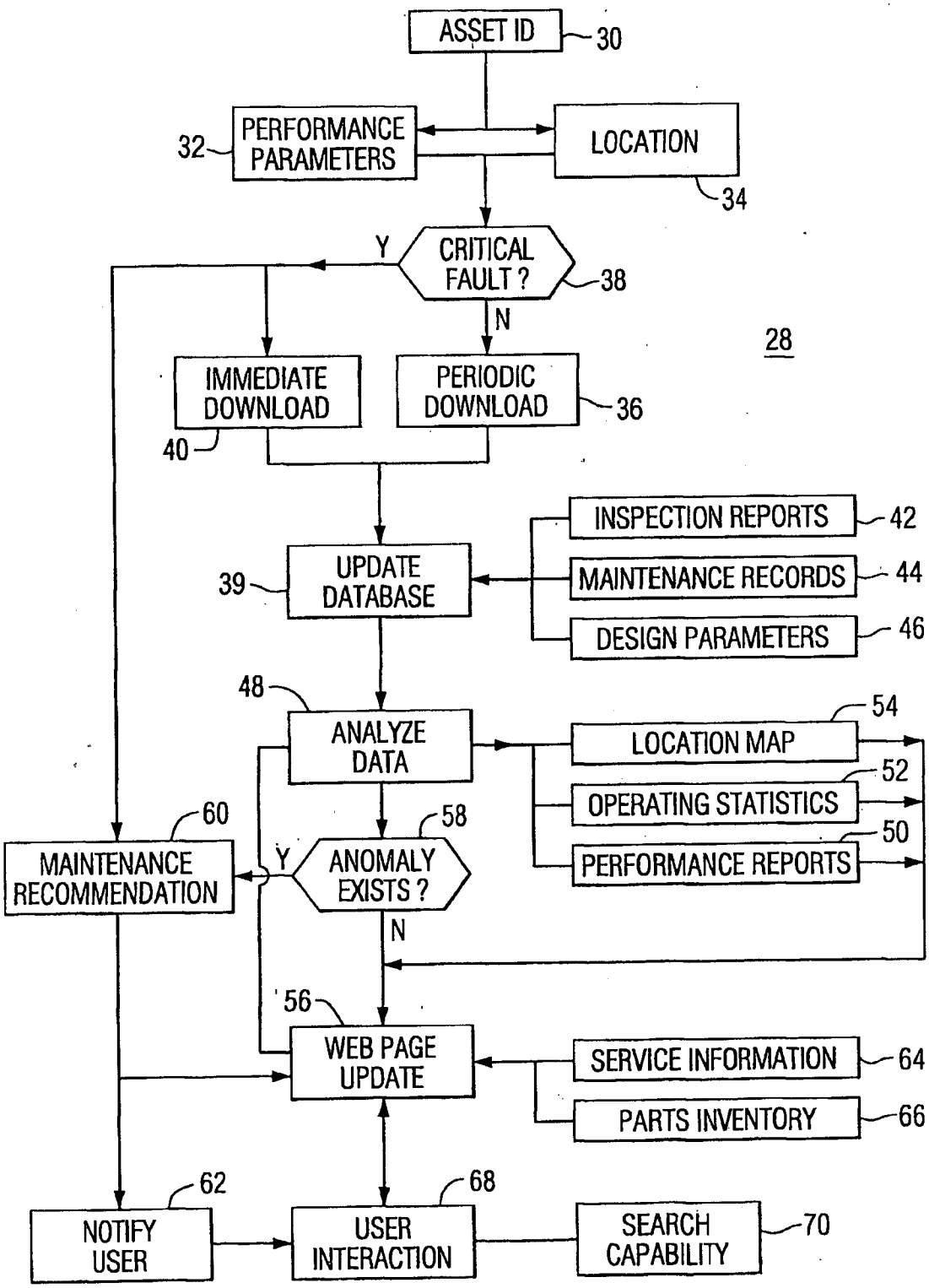

ASSET ID
30
PERFORMANCE PARAMETERS
32
LOCATION
34
Y
CRITICAL FAULT ?
38
N
28
IMMEDIATE DOWNLOAD
40
PERIODIC DOWNLOAD
36
INSPECTION REPORTS
42
UPDATE DATABASE
39
MAINTENANCE RECORDS
44
DESIGN PARAMETERS
46
48
ANALYZE DATA
54
LOCATION MAP
52
OPERATING STATISTICS
50
PERFORMANCE REPORTS
60
MAINTENANCE RECOMMENDATION
58
Y
ANOMALY EXISTS ?
N
56
WEB PAGE UPDATE
SERVICE INFORMATION
64
PARTS INVENTORY
66
62
NOTIFY USER
68
USER INTERACTION
SEARCH CAPABILITY
70

FIG. 2

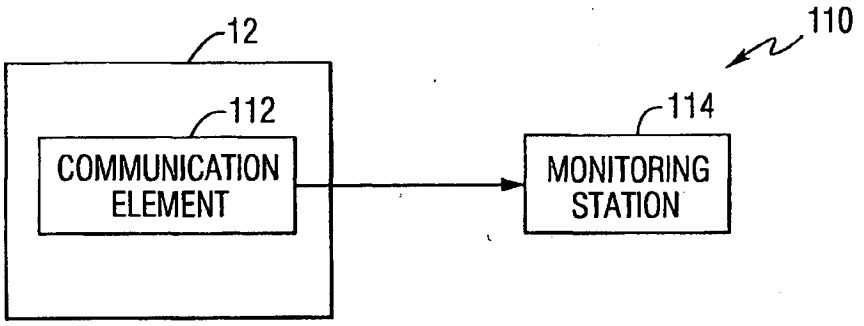

12
110
112
114
COMMUNICATION ELEMENT
MONITORING STATION

FIG. 3

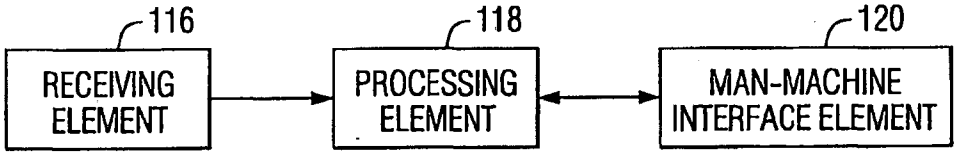

116
118
120
RECEIVING ELEMENT
PROCESSING ELEMENT
MAN-MACHINE INTERFACE ELEMENT

FIG. 4

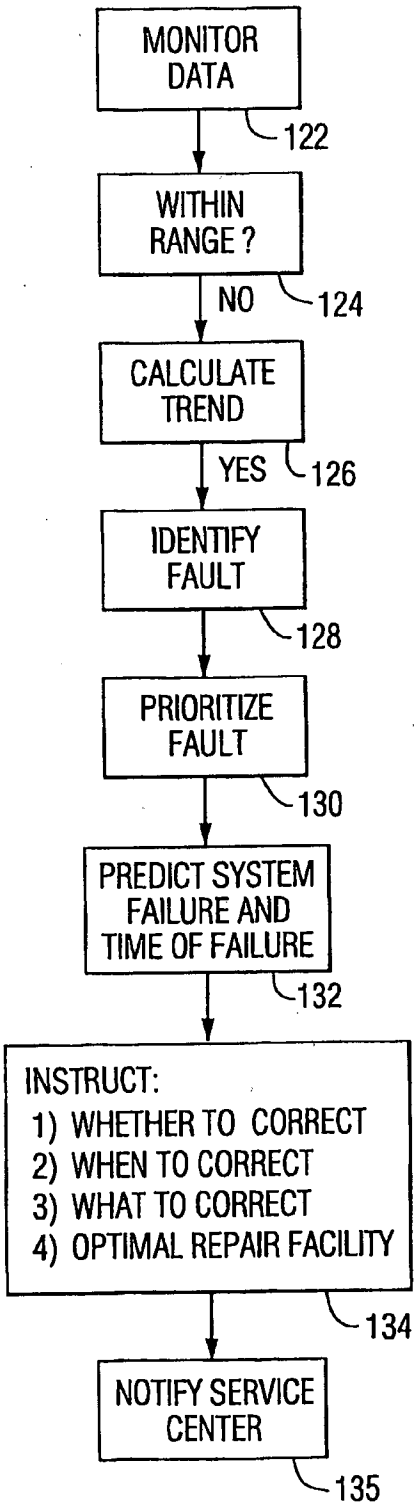

MONITOR DATA
122
WITHIN RANGE ?
NO
124
CALCULATE TREND
YES
126
IDENTIFY FAULT
128
PRIORITIZE FAULT
130
PREDICT SYSTEM FAILURE AND TIME OF FAILURE
132
INSTRUCT:
1) WHETHER TO CORRECT
2) WHEN TO CORRECT
3) WHAT TO CORRECT
4) OPTIMAL REPAIR FACILITY
134
NOTIFY SERVICE CENTER
135

FIG. 5

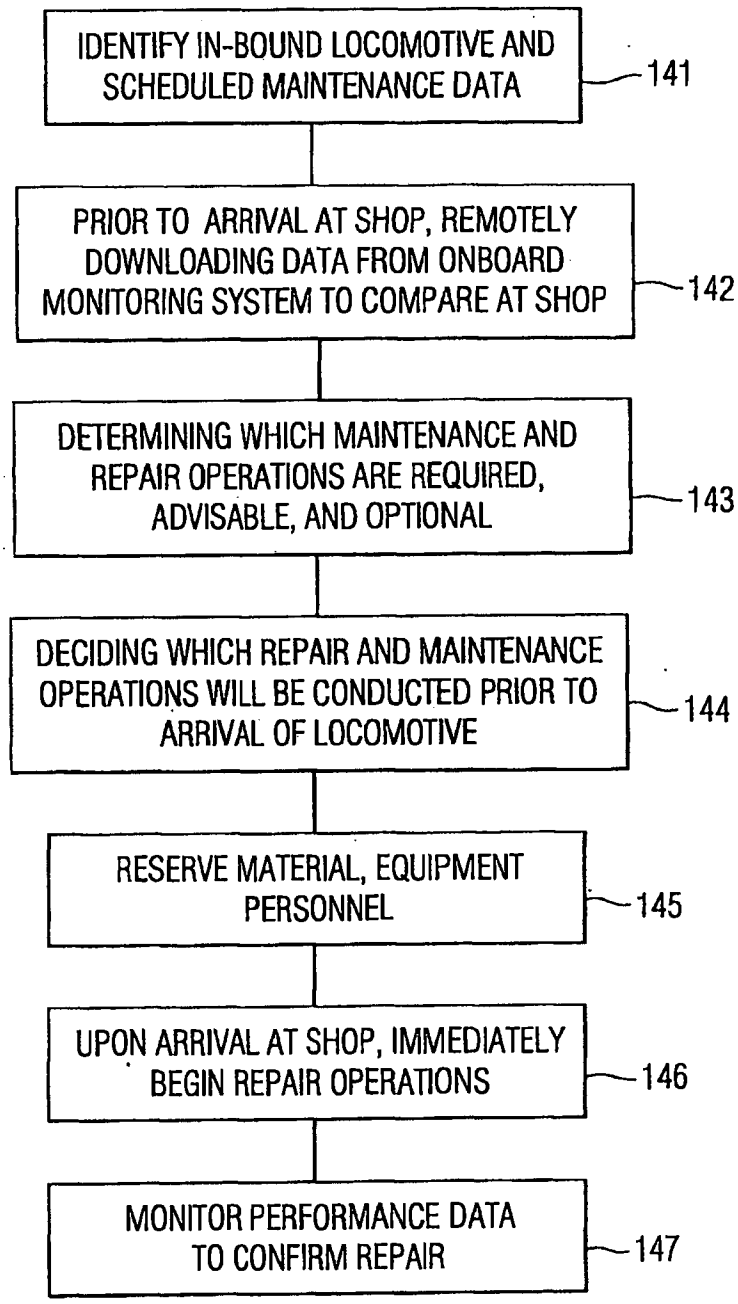

IDENTIFY IN-BOUND LOCOMOTIVE AND SCHEDULED MAINTENANCE DATA
141
PRIOR TO ARRIVAL AT SHOP, REMOTELY DOWNLOADING DATA FROM ONBOARD MONITORING SYSTEM TO COMPARE AT SHOP
142
DETERMINING WHICH MAINTENANCE AND REPAIR OPERATIONS ARE REQUIRED, ADVISABLE, AND OPTIONAL
143
DECIDING WHICH REPAIR AND MAINTENANCE OPERATIONS WILL BE CONDUCTED PRIOR TO ARRIVAL OF LOCOMOTIVE
144
RESERVE MATERIAL, EQUIPMENT PERSONNEL
145
UPON ARRIVAL AT SHOP, IMMEDIATELY BEGIN REPAIR OPERATIONS
146
MONITOR PERFORMANCE DATA TO CONFIRM REPAIR
147

FIG. 6

SUBSTITUTE SHEET (RULE 26)

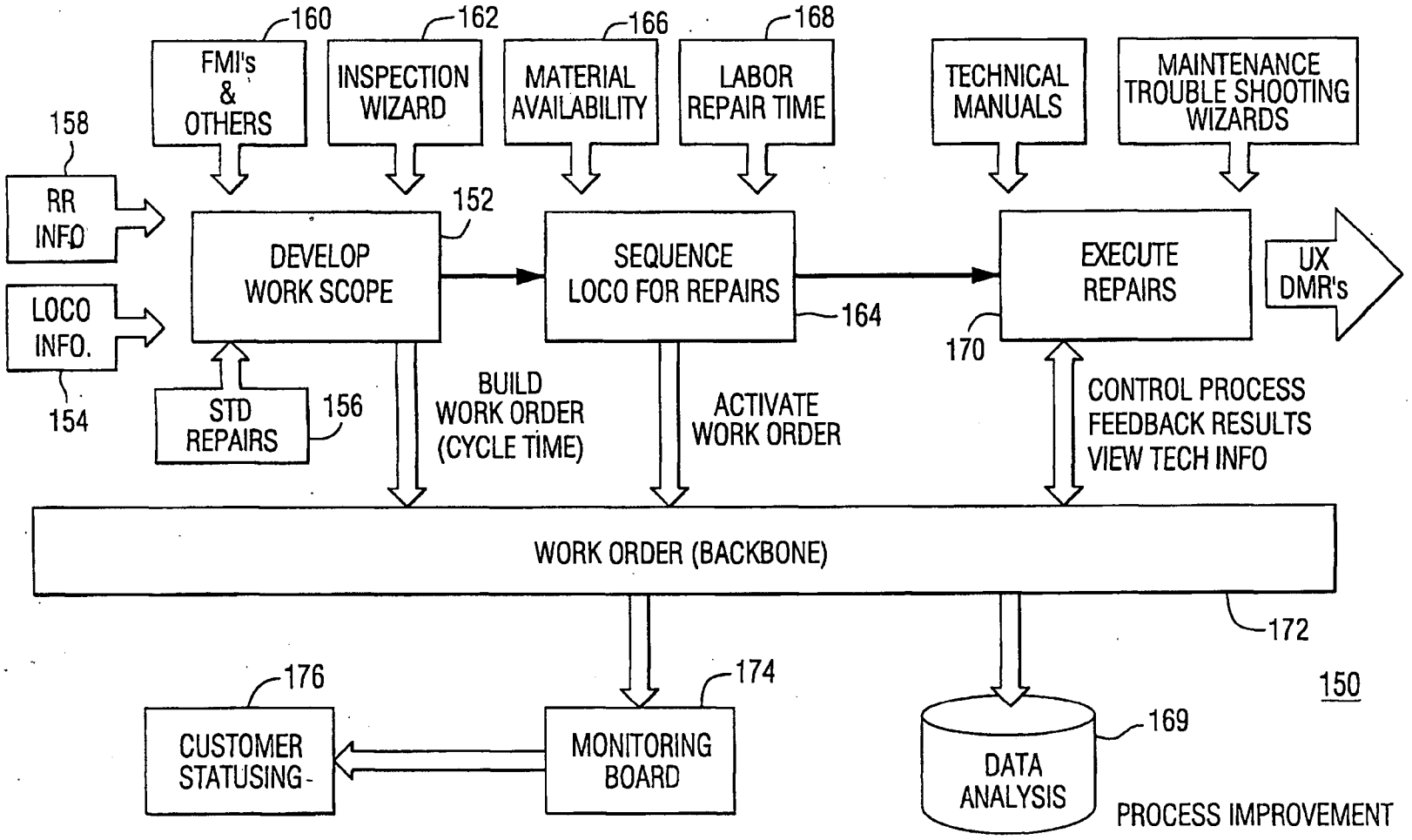


FIG. 7

7/11

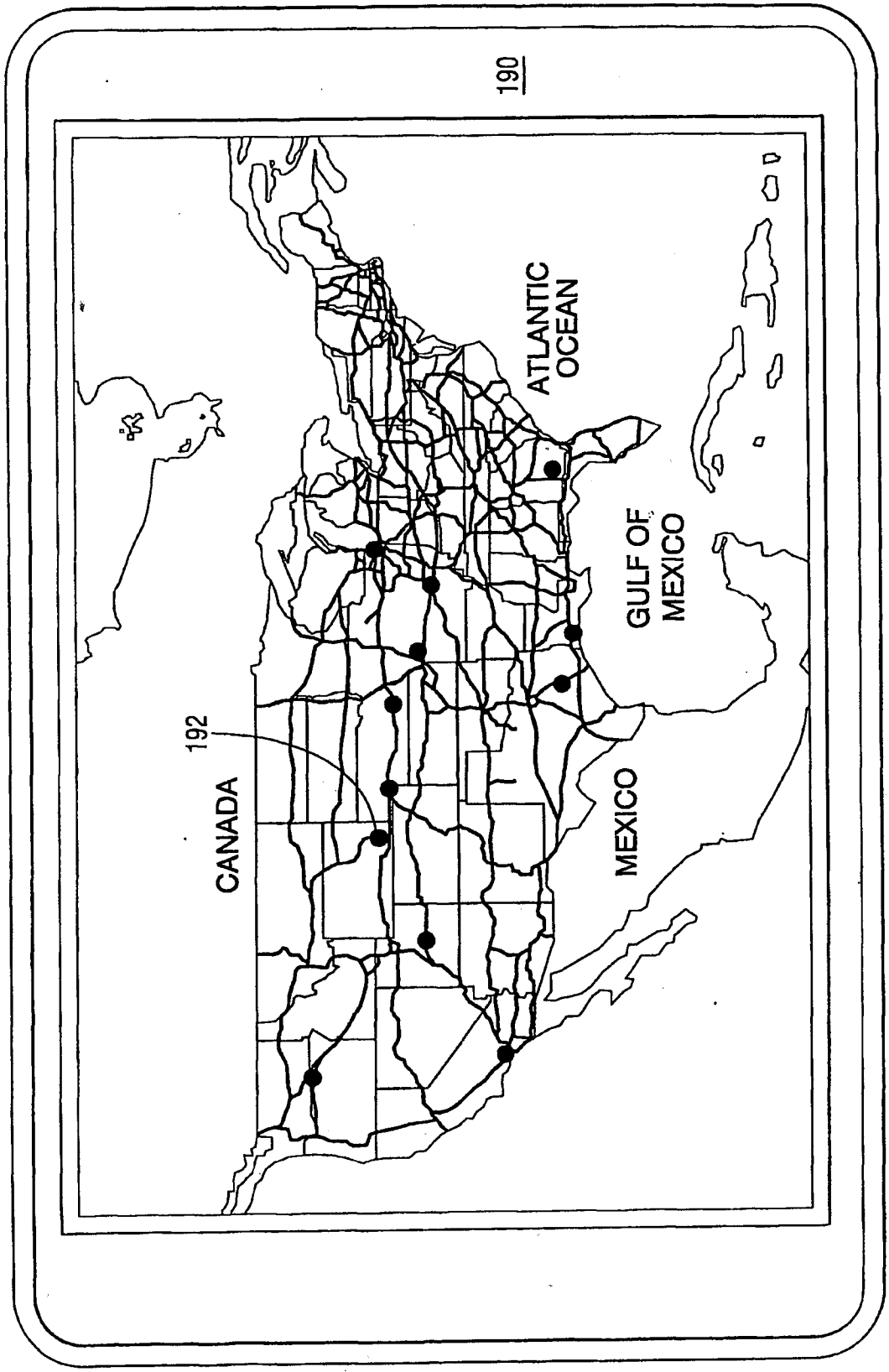


FIG. 8

SUBSTITUTE SHEET (RULE 26)

LOCOMOTIVE CITY/STATE PROXIMITY

CITY: LOS ANGELES

STATE: CA

RANGE: 100 MILES

SEND QUERY:

SUBMIT

ALL LOCOMOTIVES WITHIN 100 MILE RADIUS OF LOS ANGELES, CA	
LOCOMOTIVE	LOCATION
8618	1.9 MILES E OF CARSON, CA
8444	1.9 MILES N OF MIRA LOMA, CA
8350	1.3 MILES NW OF PEDLEY, CA

FIG. 9

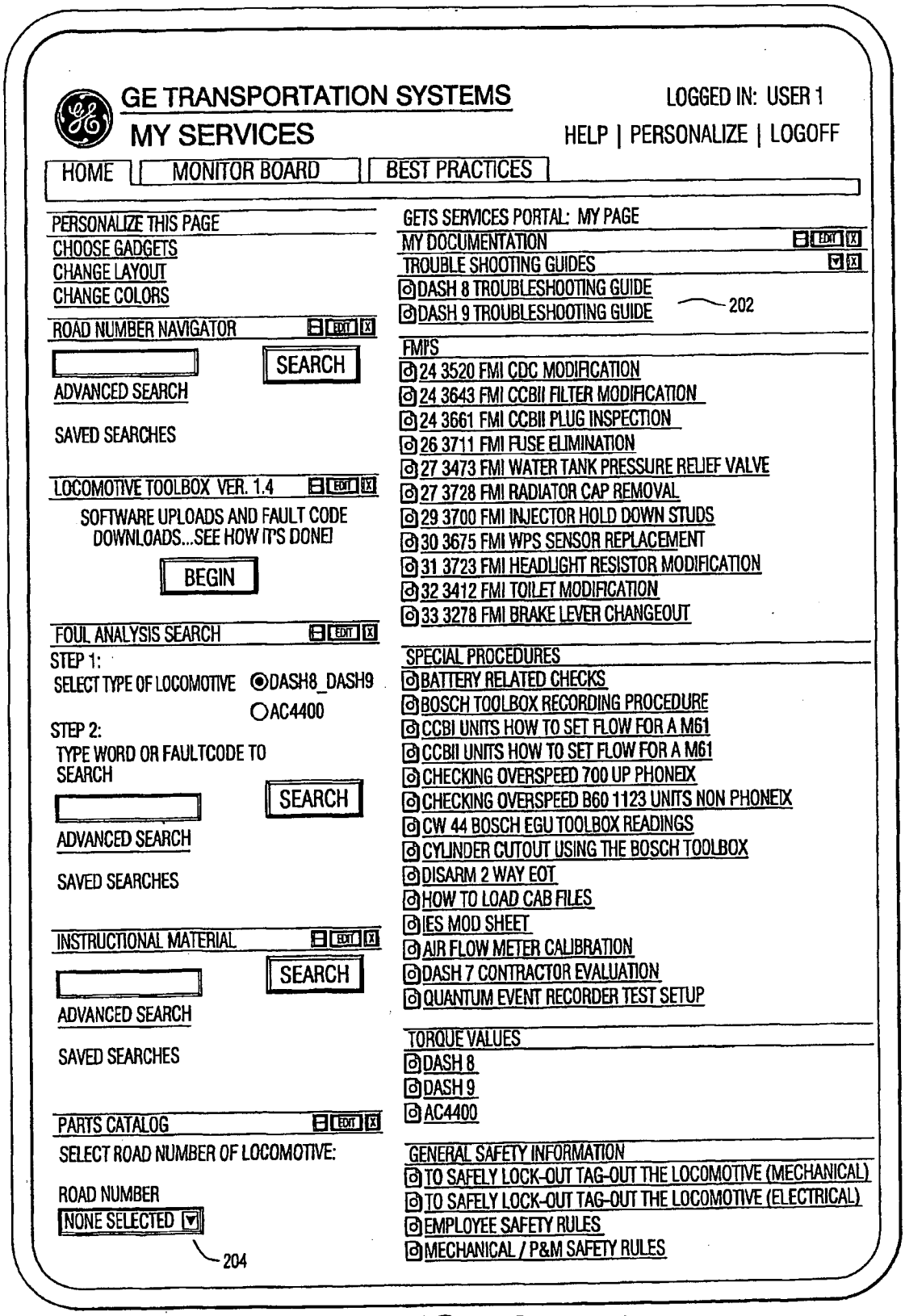


FIG. 10

SUBSTITUTE SHEET (RULE 26)

SUBSTITUTE SHEET (RULE 26)

GE TRANSPORTATION SYSTEMS

REV 0 84A207789	TROUBLESHOOTING GUIDE FOR BNSF DASH 8 LOCOMOTIVES

TROUBLESHOOTING GUIDE

FOR

BURLINGTON NORTHERN SANTA FE (BNSF) DASH 8 LOCOMOTIVES

FIG. 11

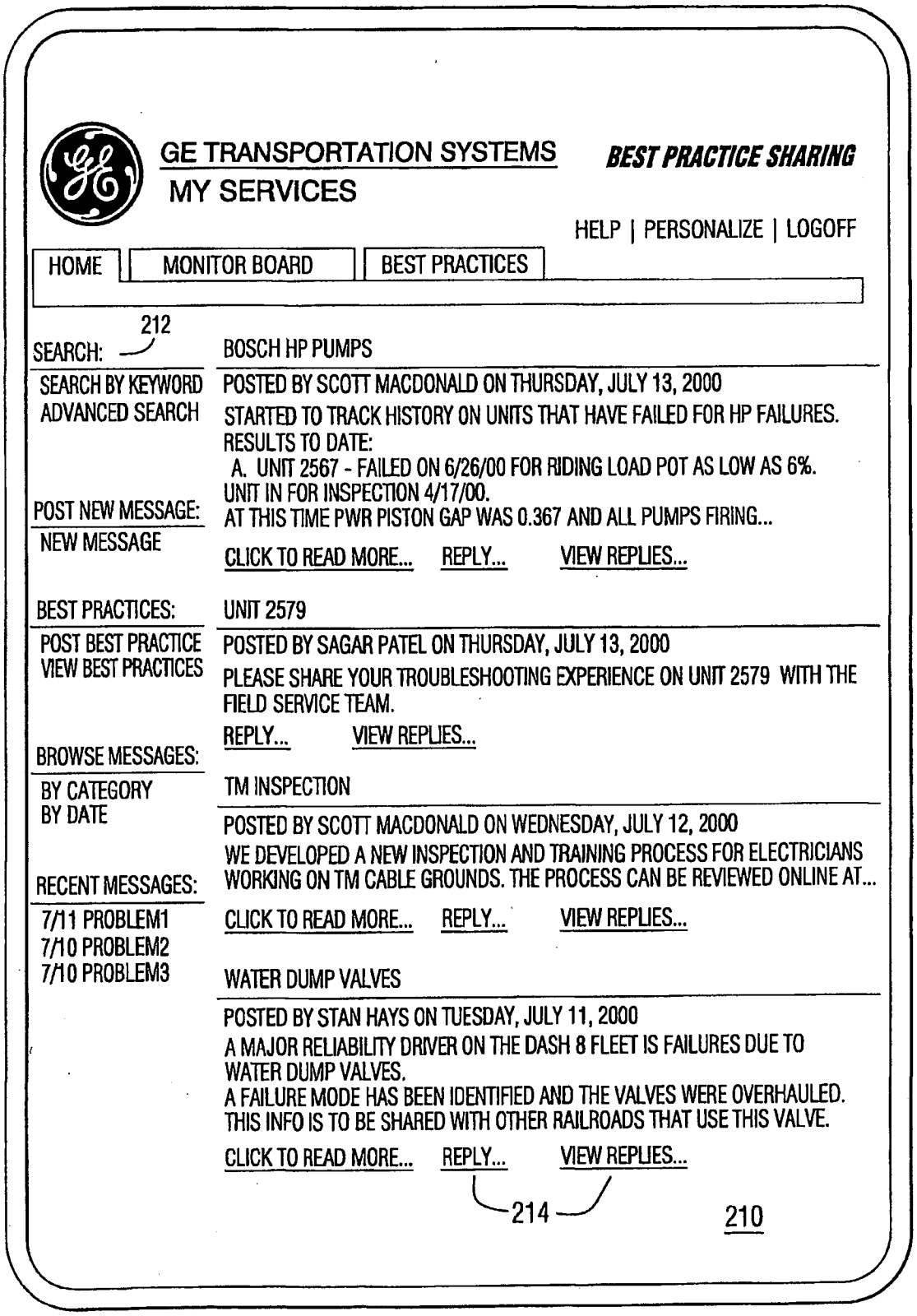


FIG. 12

SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

Ir dional Application No
PCT/US 00/23157

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F17/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 737 215 A (SARANGAPANI JAGANNATHAN ET AL) 7 April 1998 (1998-04-07) abstract claims 1-5 column 1, line 12 -column 2, line 4 figures 1-6 ---	1-47
X	WO 98 24042 A (HAO BEILENE ;ELGIN RICHARD L (US); SUNDSTRAND CORP (US);: EASTMAN D) 4 June 1998 (1998-06-04) abstract page 1, line 10 -page 10, line 3 ---	1-47
A	US 5 210 704 A (HUSSEINY ABDO A) 11 May 1993 (1993-05-11) abstract claims 1,2 ---	1-47

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 December 2002	13/12/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Daman, M

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

	ional Application No
	PCT/US 00/23157

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 845 272 A (BUSH JAMES ARTHUR ET AL) 1 December 1998 (1998-12-01) cited in the application abstract claims 1-8	1-47

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/23157

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5737215	A	07-04-1998	DE	19651986 A1	19-06-1997
			JP	9202218 A	05-08-1997
WO 9824042	A	04-06-1998	CN	1238848 A	15-12-1999
			EP	1010114 A1	21-06-2000
			JP	2001507144 T	29-05-2001
			WO	9824042 A1	04-06-1998
			US	6226597 B1	01-05-2001
US 5210704	A	11-05-1993	NONE		
US 5845272	A	01-12-1998	CA	2220720 A1	29-05-1998

Form PCT/ISA/210 (patent family annex) (July 1992)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 November 2005 (10.11.2005)

PCT

(10) International Publication Number
WO 2005/105536 A1

(51) International Patent Classification[7]: B61L 23/00, B61D 43/00

(21) International Application Number: PCT/AU2005/000624

(22) International Filing Date: 3 May 2005 (03.05.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2004902285 3 May 2004 (03.05.2004) AU

(71) Applicant *(for all designated States except US)*: **STI RAIL PTY LTD** [AU/AU]; Suite 27, Level 1, 375 Hay Street, Subiaco, W.A. 6008 (AU).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **SEARLE, Donald, Stephen** [AU/AU]; Lot 8 Bonza Place, Bindoon, W.A. 6502 (AU). **WINKINS, Charles, Richard, Wallace** [AU/AU]; 58 Thomas Street, Nedlands, W.A. 6009 (AU).

(74) Agent: **IP FIRST**; PO Box 1089, Toowong, QLD 4066 (AU).

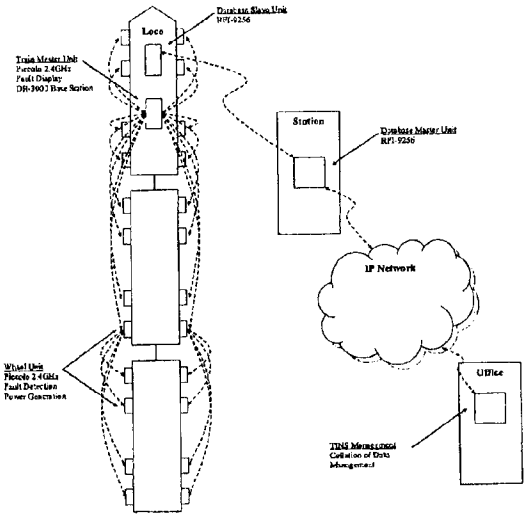
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: TRAIN INTEGRITY NETWORK SYSTEM



(57) **Abstract:** A train integrity network system comprises bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on, an onboard server which controls the bogie units and a wireless network which enables communication between the server and the bogie units. Each bogie unit is powered by an electrical generator which utilises the rotation of the bogie wheels and has a processor which compares the critical parameters against defined standards in order to issue alerts to the train driver. The wireless network utilises master/slave base band role switching, has store-and-forward nodes which convey quasi real time data to the server and utilises frequency hopping modes.

WO 2005/105536 A1

BNSDOCID: <WO_____2005105536A1_I_>

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

BNSDOCID: <WO_____2005105536A1_I_>

TRAIN INTEGRITY NETWORK SYSTEM

FIELD OF THE INVENTION

This invention relates to computerised real time wireless network communication systems for monitoring rail and other vehicular transport for component failure and other safety aspects.

BACKGROUND OF THE INVENTION

The prior art in the field of rail transport safety discloses a number of devices designed to monitor the failure of critical components such as wheels, bearings, axles and the rail itself. For example US 6,672,681 teaches a railway axle hub sensor unit for detecting vibrations in vertical and horizontal axial directions and signalling an impending failure and/or a damaged condition whereas US 5,381,692 also uses temperature sensors to signal abnormal bearing temperatures.

US 5,433,111 discloses apparatus and a method for detecting defective conditions in both the train wheels and the rail tracks using a mobile tracking unit to record the location of the latter. Similarly, US 6,435,027, US 6,471,407, US 5,631,426, US6,378,373 and US 5,022,267 all teach various combinations of motion and temperature sensors to signal component failure and US 6,474,832 teaches a self regulating axle mounted device for generating electrical energy to power such apparatus.

However there are a number of major issues involved in monitoring all the critical components of a train at the same time, especially in long freight trains, and combining the output of many sensors to warn of developing problems before a critical failure. For example running cables throughout trains is not practical as carriages and wagons are regularly shunted into and out of different trains to make up an operating consist. Cabling plugs and sockets, compatibility from operator to operator, age of wagons and access is difficult and labour intensive. Accordingly there is a need for a wireless network which sends data processed at an axle end to a server located in the prime mover where the information is processed against set rules and automatic or manual intervention commands issued.

Further the wireless communications system must have the ability to operate in an ad-hoc environment where the sensor units on the wagon wheels have no prior

knowledge of each other but must be automatically configured to cooperate with each other in a particular train consist. Also the system must have built in redundancy, that is, the monitoring system of the server in the locomotive must be ready to act in the case of a critical situation even if signalling from specific units has failed; the failed axle units must be identified and the network automatically re-established to maintain monitoring.

Another major issue is the requirement for a reliable stable power supply for the wheel monitoring and radio networking system, since freight rolling stock do not have power on board. Each wheel unit must have a small generator powered by utilising the rotation of the wheel hub and since the power generated varies with the speed of rotation of the wheel, stable regulation of the electrical energy generated is a critical issue. Finally the system must be able to interact with a range of sensor systems which gather data for transfer to the wheel processing units.

It is also desirable for a train integrity network system (TINS) to perform the following functions:

- measuring coupling tension between wagons to enable more efficient loading and train management
- monitoring pack components such as sandwich packs, yokes and air supply.
- detecting coupling failure between wagons
- monitoring wheel slip and braking malfunction
- detecting wheel damage, failure and derailment
- detecting axle fatigue
- monitoring the security of unloading and discharge doors
- monitoring wear surfaces
- monitoring wheel wear and profile
- tracing the cause of steering defects
- lighting the side of trains to ensure visibility at rail crossings
- tracking location of individual wagons
- tracking the consignment of mixed goods
- electronic monitoring of interactions with wayside operation systems
- warning rail crossing users of train proximity
- provision of warning and prevention of train to train and other collision dangers

- provision of real time monitoring of railway crossings and rail station crossovers to prevent vehicular and pedestrian accidents
- provision of an alternative to conventional signalling methods based on global information systems
- detecting and locating track failure using global information systems.

Although developed for use in trains, such integrity network systems have a wide range of potential application in a variety of vehicles such as trams, mining machinery and road trains. The network can also be used to monitor and relay structural integrity and to collect data and security information in a range of applications such as buildings, bridges, engineering infrastructure and public places.

OBJECT OF THE INVENTION

It is therefore an object of the present invention to provide a train integrity network system (TINS) which has some of the above functions or at least provides a useful alternative to prior art systems.

STATEMENT OF THE INVENTION

According to the present invention a train integrity network system comprises two or more bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on, an onboard server which controls the bogie units and a wireless network which enables communication between the server and the bogie units.

Preferably the bogie units have sensors to monitor the temperature of the wheel hubs of the bogie.

Preferably the bogie units have sensors to monitor the temperature of the wheel perimeters of the bogie.

Preferably the bogie units have motion detectors to monitor movement of the bogie axle in vertical and horizontal directions.

Preferably the bogie units have accelerometers to monitor acceleration of the bogie axle.

Preferably the bogie units have means to measure the speed of rotation of the bogie wheels.

Preferably the bogie units are powered by an electrical generator which utilises the rotation of the bogie wheels.

Preferably the bogie units have a processor which compares the critical parameters against defined standards.

Preferably the bogie units have a wireless transceiver which enables communication with other bogie units and the server.

Preferably the bogie units have a source of illumination.

Preferably the wireless network utilises master/slave base band role switching.

Preferably the wireless network has store-and-forward nodes which convey quasi real time data to the server.

Preferably the wireless network has frequency hopping modes.

Preferably the server can download data to a wayside database.

Preferably the system has a GPS unit to record the location of the train at any time.

Preferably the system has an end-of-train monitoring function.

Preferably the system has a collision avoidance function.

Preferably the system has a level crossing warning function.

Preferably the system transmits a warning signal to vehicles approaching a level crossing which are equipped to receive said signal.

Preferably the system monitors tension and compression in the train wagon couplings.

BRIEF DESCRIPTION OF THE DRAWINGS

A particular embodiment of the invention is now described by way of example only with reference to the accompanying drawings in which:

Figure 1 illustrates the general arrangement of the store and forward function of individual bogie units and their master/slave automatic configuration,

Figure 2 illustrates the overall network architecture of the system,

Figure 3 illustrates the architecture of a bogie unit ,

Figure 4 shows the sensor circuit board layout of a bogie unit,

Figure 5 illustrates the server architecture,

Figure 6 illustrates a TINS network of 4 unit depth and 3 unit width,

Figure 7 illustrates the TINS network of Figure 6 during the establishment phase,

Figure 8 illustrates the basic establishment methodology of the TINS network,

Figure 9 illustrates the network discovery messaging of the TINS network,

BNSDOCID: <WO_____2005105536A1_I_>

Figure 10 illustrates the RSSI and wheel number division of time during network discovery,

Figure 11 illustrates the extension of the network,

Figure 12 is the network establishment flowchart,

Figure 13 shows the network establishment frequency use,

Figure 14 shows the progression of hopping channel with each control frame,

Figure 15 shows an ideal coverage map for a network of 5 unit depth and 2 unit width,

Figure 16 is a transmit data flowchart,

Figure 17 is a receive data flowchart,

Figure 18 shows the RF section of a bogie unit,

Figure 19 is a schematic of a bogie unit,

Figure 20 is a photograph of a bogie unit,

Figure 21 shows the layout of a bogie unit with remote infrared censor and

Figure 22 is a schematic of the bogie unit software architecture.

DETAILED DESCRIPTION OF THE INVENTION

The TINS has two main components, namely, the bogie units which incorporate the wireless communication system, and the onboard server unit. The bogie units monitor in real time various wheel and track factors including rotation, vibration, g-force acceleration and bearing temperature, as well as the causes of differential temperature effects. The information is analysed in a processor in the bogie unit by means of algorithms which have been developed to recognise a range of specific component conditions. If a monitored condition exceeds a predetermined threshold or parameter the processor will generate an alarm which is transmitted via a RF network to the server. The server then notifies the driver via a control console, of the specific exception, including the condition, the position of the bogie in the train consist, the last ten minutes of trend information and a menu of corrective actions to be taken.

The bogie units comprise:

- various temperature, motion and acceleration sensors

- a microprocessor to analyse signals from the sensors
- non volatile memory for data storage
- a radio modem for communicating with the on board server and other bogie units
- a power generation and regulation system
- an external housing
- programming software
- an antenna and
- strobe lighting

The server comprises:

- a laptop or other personal computer
- three radios and related modems
- antennas
- a GPS transponder
- programming software
- a data storage device
- and a video compression engine

The bogie units can detect:

- a hot axle box
- flat and broken wheels
- wheel slip and wheel derailment
- end-of-train and train handling
- brake failure and hot wheels
- hunting wheel sets and
- track conditions such as corrugations, cracked and broken rails and horizontal and vertical defects.

The core of the TINS is a RF/Digital wireless communications backbone which links the monitoring and processing hardware and software of the bogie units with the server and each other. The units are installed on each end of a bogie and monitor a range of parameters which detect the above conditions. This information is then relayed through the wireless backbone to alert the driver to intervene manually or to trigger an automatic response in critical situations. There is a "heart beat" protocol

within the TINS which establishes that the bogie units are on-line and fully operational and reports any that have failed. Accordingly the TINS not only guards against derailments but improves performance and efficiency thus reducing operational costs.

A critical aspect of the TINS is the ability of the bogie units to self-configure, that is when wagons are coupled into a train consist there is no shared information between the units and the server. However, once the consist is assembled and the units power up , they can be either manually or automatically booted so that they start to communicate with each other and within several minutes become united in the one network with the sever to provide whole train integrity. If one of the units fails the adjacent units leap-frog to the next operating unit to maintain the train's "heart beat" which is essential for operational redundancy. Since it has an open architecture, the TINS can also host a range of additional "smart" monitoring and warning systems such as collision avoidance.

Figures 1 and 2 illustrate the overall network architecture between the units, the server, a database slave unit, both located in the loco, a database located in a station and a remote management server. When the train powers up, the server establishes a fully connected network of master, repeater, and slave units. This network then transmits signals generated by the sensors to the server where the data is collated. As the train passes through a station, a radio modem is used to download the data to a wayside database which is connected to a remote management server via an IP network. The station databases provide the statistics for final collation and analysis by the management server.

Figures 19 and 20 show a schematic and a photographic view respectively of the bogie units while Figures 3 and 4 illustrate their architecture and sensor circuit board layout respectively. The power required for each unit is generated by a multiphase AC alternator in which the stator is the coil assembly and the magnets are fixed to a circular disc that spins at wheel velocity. The multiphase AC output is proportional to wheel velocity (within certain constraints) and is rectified, regulated and processed by a regulator module.

The power regulator supplies power to a single Piccolo radio module PCB shown in Figure 18, the sensor circuit board as shown in Figure 4, and the sensors; the Piccolo module is powered directly but the other components are only supplied with power when the Piccolo has become active and enables the sensor power switch. The sensor power switch is only activated when the Piccolo has determined that there is sufficient power from the bogie units to supply the sensor sub-system; this is done my monitoring the raw voltage output of the power supply regulator circuit.

There are two temperature sensors, one for sensing the temperature of the hub of the wheel, and hence the inferred bearing temperature, and the other for measuring the temperature at the periphery of the wheel by infrared means as shown in Figure 21. The outputs of the sensors are analog DC voltages proportional to temperature and are converted to digital signals via an analog to digital converter (ADC). These signals are then converted to degrees C, low-pass filtered, and compared against alarm triggering levels. If the filtered temperature exceeds the prescribed alarm level an alarm is triggered and is not cleared until the temperature falls below a second prescribed level, thus providing hysteresis.

Vibrations in the vertical and horizontal planes of the wheel are measured by two orthogonally mounted accelerometers. The accelerometer outputs are analog DC proportional to acceleration between defined limits. These outputs are converted to digital via an ADC, converted from ADC units (voltage) into real-world units (G's), low-pass filtered, and compared against an alarm level. If the filtered acceleration exceeds the prescribed alarm level, then an alarm is generated. Approximate wheel velocity is derived from the power generator supply voltage which is divided down and converted to digital via an ADC. The result is then converted into a voltage which is proportional to rate of rotation. However precise wheel velocity is determined by a Hall Effect device attached to the rotating magnet assembly which produces a pulse output for each completed wheel revolution.

The microprocessor module of the bogie units uses high speed programmable logic arrays to process the incoming data from the sensors described above so that it is not overloaded with tasks which reduce its response time and limit its ability to control the RF section. A flow diagram of the programming software for the units is given in

Figure 22. Communication between the processing module and the microprocessor module is via a parallel bus which enables the fastest communications possible. This module performs the following functions:

- Processing alarms generated by the module and activating the data radio.
- Providing instructions to the processing module.
- Providing non-volatile storage of temperature and vibration data for continuous transmission in the event of a valid alarm condition.
- Managing a serial data protocol for external communications and programming.
- Establishing routines for "heartbeat" responses
- Managing the data radio background functions.
- Managing store and forward functionality and redundancy.

A high speed digital radio which has its power and antenna outputs controlled by the microprocessor module is used to transmit to and receive from other bogie units and the server. The radio performs dual roles of a network repeater or an end point station depending on the network configuration and its position in the train consist. The antenna system is designed to focus the RF energy forward and backward along the axis of the train so that other units will be radiated by the RF lobe maxima. The range of the signal is controlled by the power output of the transmitter which is in turn controlled by the microprocessor. Spectrum reuse is paramount in a very long consist and so the range of the units' data radio has to be controlled.

Figure 5 is a schematic of the six components of the server namely a network protocol parser and generator, a service layer, an automatic network control and data gathering, real time trending, data storage and trending and a user interface. The protocol generator and parser generates request packets for the data radio and parses response packets for the service layer to interpret. The service layer provides individual status of the wheel with alarm reporting, individual status of the wheel without alarm reporting, and network status and alarm reporting on the entire network.

The automatic network control and data gathering performs automatic status retrieval from bogie units on the network, alarm generation from status retrieved, individual

monitoring of units and interface to real-time graphical trending. The latter also displays data graphically as it arrives in the automatic network control and data gathering component and visually indicates alarm conditions. The data storage and trending includes a database with the option to graph the time stamped data stored and to apply algorithms to it. Connection from the server to the bogie units is via a data radio and the server can be connected to an external wireless network such as a satellite data modem or a WLAN or any standard data radio in order to report to a remote management centre.

The TINS wireless network architecture is shown in Figure 6 as a series of interconnected units arranged in layers having a depth of four units and a width of three units. The depth of a network is the maximum number of units that a message must travel through in order for it to move between the master and the furthest unit and the width is the maximum number of units in each layer.

The network can be in one of two modes, an establishment mode or an operational mode. In the former one unit from each layer is designated as the primary and only that unit can transmit messages to or receive messages from units below it in the network as shown in Figure 6. In the latter mode any units in layer *n* can communicate with units in layers *n+1* and *n-1*. In this scenario each unit communicates with a single unit in the lower layer, and a single unit the upper layer, effectively creating a number of different networks equal to the network width. A unit may communicate with more than one unit in the layer above or below it and in the network establishment mode shown in Figure 7, only M_{00}, U_{10}, U_{21}, and U_{30} can transmit messages to units in lower layers or receive messages from units in lower layers. A maximum of 6 units per layer is supported within the network.

The TINS wireless network also uses a time division store and forward communications architecture with multiple redundant communication paths while in full operation. All data is transmitted in fixed width slots and any one slot may contain one or two frames depending on the format of the slot. There are three types of slots downlink, uplink and connect. A downlink slot contains data to be transmitted from the master to a single unit or to all units. Data transmitted in a downlink slot is not acknowledged by receiving units within the same downlink slot. Downlink slots are used to transmit data down the communications network. An uplink slot contains data to be transmitted from a single unit to the master. Data transmitted in an uplink slot is

acknowledged by the receiving unit within the slot. Uplink slots are used to transmit data up the communications network. A connect slot allows unconnected units to announce themselves and permit connection to the network.

Accordingly there are two distinct communications behaviours in the TINS wireless network. When the network establishment mode is entered during start-up the set of available units is discovered, and the role of each unit in normal operation is allocated. While undertaking network establishment, there is no redundancy and a unit failure will result in the restarting of network establishment. Once the network has been established, the operational mode is entered and the network supports multiple redundant communication paths. In this mode the network performs the following functions. The units asynchronously report alarm conditions to the master; the alarms are propagated from the generating unit to the master via the communications network. The stati of the sensors on a single unit are reported to the master in real-time; the last ten minutes of data for the internal sensors is also transmitted to the master when this function is operating. The units also pass on debugging information.

In the following description of the TINS network, when a unit A is above unit B there are fewer hops between the master and unit A than between the master and unit B. And when unit A is below unit B, then there are more hops between the master and unit A, than between the master and unit B. Each unit in the TINS network has three pre-configured addresses, and one dynamically allocated address. The three pre-configured addresses are:

- Globally Unique Identifier (GUID): A 32-bit factory configured address.
- Carriage Identifier (CID): A 25-bit user configured address. All wheel units on the same carriage must have the same carriage address.
- Wheel Number: A 3-bit user configured address. This indicates which wheel on the carriage a particular unit relates to. The wheel numbering can be found in the PRS.

The wheel number of carriage identifier go together to form a 32-bit Carriage Unique Identifier (CUID). The dynamically assigned address is the Dynamically Allocated

Hopping Pattern (DAHP). The DAHP sets the frequencies that the unit transmits and receives on, and uniquely identifies the unit in the network.

In the following sections a number of symbols are used to represent various network configuration and timing parameters. These are shown below.

d The depth of the network.

w The maximum width of the network.

b_m The number of bytes in a monitoring upload slot.

m The amount of bandwidth (in bits per second) available for monitoring.

n_c The number of channels.

n_u The number of uplink slots per downlink slot used in normal operation.

$t_e(x)$ The amount of time (in seconds) required to complete a request or response cycle during network establishment for a network of depth x.

$t_d(x)$ The amount of time (in seconds) required to complete a single discovery cycle on a network of depth x.

$t_{down}(x)$ The amount of time (in seconds) required for a message to propagate from the master to a unit at depth x. This is only applicable in normal operation.

$t_{up}(x)$ The amount of time (in seconds) required for a message to propagate from a unit at depth x to the master. This is only applicable in normal operation.

$t_x(x)$ The amount of time (in seconds) required to complete a single network extension on a network of depth x.

t_l The total time taken to achieve lock.

BNSDOCID: <WO_____2005105536A1_I_>

t_n The total amount of time (in seconds) required to complete network establishment.

t_s The slot time in seconds.

r The number of transmissions required to successfully receive a data frame. For example, $r = 1$ implies that 100% of packets get through on the first attempt, with $r = 1.5$ implies that 50% of packets get through on the first attempt.

s_d The number of slots to spend performing network discovery.

When a unit first powers up in network establishment mode it enters the unconnected state and behaves as follows. It listens on a single channel for $(n_c+1)t_s$ ms, where n_c is the number of channels and t_s is the maximum slot time. After this time it moves to the next channel and continue listening. If a downlink frame is detected it checks the child address list for this unit's GUID. If it is found it then locks and hops with that unit. If a connect frame is detected, it locks and hops with that unit until the connect frames stop being transmitted and generates connect responses occasionally until acknowledged.

Network establishment is controlled by the master unit in the locomotive and the TINS network operates in a simple request / response mode as shown in Figure 8. Requests are generated by the master, and each unit continually re-transmits the same request until the master changes the request it is transmitting. Each request is directed to a single unit. Once the unit has completed the request, it passes a response back to the master via the network.

In Figure 8 a request is inserted in slot 0 and propagated down to U_{30}, where a response is generated which returns to the master in slot 9. The master spends half of its time talking to one side of the train as shown and the other half of its slots are used to communicate with the other side of the train. Lost requests are handled by the downlink constantly sending the same message until the master changes it. This will not happen until a response is received or a timeout occurs. Lost responses are handled by retries within the uplink frame.

When using this scheme, the amount of time required to transmit a request from the master to its destination, or from a unit to the master is given by:

$$t_e(x) = t_s[2r(x-1)]$$

where x is the depth of the unit. All master generated requests have an associated timeout period. If a response is not received before the timeout expires then the transmitted request is considered lost. This causes the restart of network establishment which has two basic operations, network discovery where a single unit is instructed by the master to discover what other to discover what other unconnected units are available for communications and network extension where a single unit is instructed to extend the communications network.

The messages used to perform network discovery are shown in Figure 9 where a DISCOVER-REQ message is transmitted from the master, and propagated down to a single destination. When the destination of the DISCOVER-REQ message receives it, the unit enters discovery mode and allows all unconnected units to transmit CONNECT messages. The connect message contains the following information: the GUID and the CUID of the transmitter, the RSSI between the connected and unconnected units and the number of failed connect attempts. Each CONNECT message is acknowledged by the connected unit. Once an unconnected unit has been acknowledged, it no longer attempts to transmit. The number of slots available for unconnected units to transmit is broadcast by the connected unit. The time taken for an unlocked unit to achieve lock with a unit that is transmitting CONNECT messages is given by:

$$t_l = r(n_c + 1)t_s$$

Thus, the number of slots allocated to locking must take into account this period of potential dead-time at the start.

The parameters for received signal strength intensity (RSSI) and wheel number are available for controlling unconnected unit transmissions to minimise the possibility of collision. During the first phase of connection there is no restriction, however during the second phase the air time is divided such that RSSI and wheel number select the slots that unconnected units may transmit as shown in Figure 10

Network extension occurs after network discovery and is used to extend the network by adding an additional layer. The messages used for network extension are shown in Figure 11 If network discovery is performed by U_{30}, then the network extension command will be passed to U_{20}. It is then the responsibility of U_{20} to pass the network extension command to all its children (U_{30} through U_{33}) and verify that each one received the command. The network extension request contains the following information: the DAHP for each unit in the layer below the destination, the children of each unit the layer below the destination and the primary for each child of the layer below the destination. When using this scheme, the amount of time required to perform network extension for a single layer at depth x is given by:

$$t_x(x) = 2t_e(x) + 4r.w.t_s$$

The flowchart for network establishment is shown in Figure 12as a repetitive two step process. In the first step the available units are discovered, while in the second step the network is extended to accept these new units. This process is repeated until no new units are discovered. Network establishment is $O(d^2)$ in complexity. The total time required to perform network establishment is given by:

$$\begin{aligned}
t_n &= \sum_{x=1}^{d}\left(t_d(x) + t_x(x)\right) \\
&= \sum_{x=1}^{d}\left(2t_e(x) + t_s s_d + 2t_e(x) + 4t_s rw\right) \\
&= \sum_{x=1}^{d} 4t_e(x) + \left(ds_d + 4drw\right)t_s \\
&= \sum_{x=1}^{d} 4t_s[2r(x-1)] + \left(ds_d + 4drw\right)t_s \\
&= 8t_s r\sum_{x=1}^{d} x - 8t_s r + \left(ds_d + 4drw\right)t_s \\
&= 4t_s r\left(d^2 + d\right) - 8t_s r + \left(ds_d + 4drw\right)t_s \\
&= t_s\left(4rd^2 + 4rd - 8r + ds_d + 4drw\right)
\end{aligned}$$

The US Federal Communications Commission's regulations (Part 15.247) for frequency hopping systems in 2.4GHz state:

> *(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The*

system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

And:

(ii) Frequency hopping systems operating in the 2400–2483.5 MHz and 5725–5850 MHz bands shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

The major feature of these requirements is that on average, each frequency must be used with the same regularity and the occupancy of any frequency must not be greater than 0.4 seconds in any 30 second period. The wheel units use a set of 256 unique hopping patterns. All hopping patterns are of a fixed length equal to the number of available channels, where each channel is visited exactly once. Hopping pattern position is derived from the master, thus each unit in the network visits the first channel in its hopping pattern at the same time. Based on these properties, hopping patterns can be selected that minimize interference.

The allocation of frequencies during network establishment shown in Figure 13 is unbiased ie no favour is given to any particular frequency, nor is any particular frequency used for a particular purpose. Each transmitter effectively uses two hopping patterns equally, its own and the hopping pattern of the unit above. Thus, on average each frequency is used with the same regularity by each transmitter as both hopping patterns contain all frequencies. The hopping pattern progresses by 1 each time the master transmits a downlink slot. The connect slots use the hopping patterns by progressing the hopping pattern index by one on each slot. When in operational mode as shown in Figure 14, a change in frequency (progression through

the hopping pattern) occurs with each control frame the hopping channel index increases by 1 for each control frame.

The downlink frame contains two parameters used to control hopping pattern progression: the offset number which is the number of slots that the transmitters downlink frame transmission is offset from the master's downlink frame transmission and the current hopping pattern index number which gives the transmit frequency.

Hopping patterns can be calculated for minimum interference by using the following properties of the network:

- Units are arranged in layers, where any unit in layer n can hear units in layer *n+1* and *n-1*. We will also assume that it is possible to hear units in layers *n+p* and *n-p*, where *p* is the RF propagation factor.
- Units on either side of the train cannot hear each other.
- Each unit visits the same index in a hopping pattern at the same time.

Thus, the following rules apply to the hopping patterns: 256 hopping patterns must be generated and no set of *w(2p+1)* sequential hopping patterns have a collision in any channel. The TINS hopping pattern sequences are calculated using a linear congruent generator (LCG) of the form:

$$y_{n+1} = (ay_n + b) \bmod m$$

The minimum standard (MINSTD) generator is used, having constants:

$$m = 2^{31} - 1 = 2147483647$$
$$a = 7^5 = 16807$$
$$b = 0$$

The result of the LCG is to pick one of the remaining frequencies for each hopping pattern, where frequencies that would interfere are not allowed to be selected.

Accordingly the TINS provides real time monitoring of critical factors and impact risk assessment of failure immediately and not at some future time or distant monitoring wayside station. There exists an immediate option for the driver to decide whether to stop the train, reduce speed till the defective wagon can be removed form the consist

or take other action. All the while real time monitoring of the alarm condition is displayed to the driver including the last ten minutes of operation since the condition occurred . A decision can be made on the validity of the alarm, the event that may have caused the alarm and therefore the expected risk of continuing.

The TINS system also provides an end-of-train monitoring system via the bogie units of the last wagon without the need for additional equipment and is independent of the length of the train or the effect of tunnels or terrain, unlike existing wireless end-of-train systems. By installing train simulation software (TSS) into the TINS server the compressive or tension condition across each coupling along the length of the train can also be monitored. This feature enables the driver to better manage train dynamics as well as run in and run out. By integrating a GPS unit the TINS network offers additional anti-collision features between the end of the train and a following locomotive entering a proximity envelope.

By installing ACS data common protocol (DCPS) transponders, interface and software in the server, the TINS system also provides an effective low cost anti-collision system. When any two trains fall within the ACS footprint operating range, which will depend on terrain but is generally a five kilometre separation, the server will draw the driver's attention to the interaction of the approaching trains. This range can be extended as required at specific locations by the installation of permanent wayside repeaters.

The display on the locomotive server will show the relative velocity of each train, the distance of separation to a one metre resolution, a spatial map showing the position of and proximity to track infrastructure, including which track each trains occupies, which determines the risk of collision. This information will give drivers sufficient warning to react immediately or to contact a traffic controller for instructions. Accordingly, following train movements can be kept at a minimum separation regardless of visibility and cruise control options with locomotive throttle mechanisms also become possible.

By installing a database of GPS positions of all road/rail crossings on the rail system and installing a transponder at each crossing, a crossing warning system can also be incorporated into the TINS. A radio broadcast is made continuously identifying the

crossing with its code name with the broadcast range varied by the power of the radio system. With optimum antenna configuration and design, a range at maximum power of 2.5 kilometres is achievable. When the proximity switching system installed at a road crossing senses that the crossing is, or is about to be obstructed by a vehicle or person, or in the case of an actively protected crossing the boom gates or bells are functioning, but fouled by traffic or people, the video system is activated. A real time video capture of the crossing is broadcast over the 2.5 kilometre range of the system.

When a train enters the 2.5 km crossing footprint or greater footprint if repeaters are installed, the crossing ID is recognised, tested for functionality and logged as such in the server database. Crossings not functioning are reported at specific reporting points along the route or can be reported online with satellite communications separately installed. The video capture of the crossing is stored in the server until the train has cleared the crossing. Accordingly, the driver is able to ascertain any risk prior to reaching the crossing and to take appropriate action. In the event that the time to stop the train is inadequate the system provides the train operator with a clear record of the responsible party to the accident.

If no proximity switches are activated, the crossing is logged in the database as being functional but no image is displayed to the locomotive driver. A record of events is collected and stored whilst the train itself intercepts the crossing. In the case of multiple crossings, the imagery is stacked sequentially based on the closest first. Where an accident occurs, the video capture will record the events creating the accident, whether the cause of the track being fouled was before the arrival of the locomotive or after, in the case of a crash into the side of the train. The video capture is terminated once the train clears the crossing and if no interjection is made by the driver as a vigilance procedure the record is removed from the storage device for the particular crossing. This system is also able to transmit a warning signal to vehicles approaching a level crossing which are equipped to receive the signal and so reduces the train whistle objections raised by local residents.

The surplus power generated by the bogie units whilst the train is in motion is used to operate strobe lighting on units thus illuminating the full length of the train and

improving its visibility side on. When the train is stationary the strobe lighting ceases and the bogie units go into hibernation mode.

VARIATIONS

It will be realized that the foregoing has been given by way of illustrative example only and that all other modifications and variations as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of the invention as herein set forth. In particular it will be apparent that the TINS could be applied to vehicular systems other than trains and systems which have characteristics similar to trains such as security monitoring systems.

Throughout the description and claims to this specification the word "comprise" and variations of that word such as "comprises " and "comprising" are not intended to exclude other additives, components, integers or steps.

CLAIMS

1. A train integrity network system comprising two or more bogie units which monitor critical parameters relating to the condition of bogie components and the rail track they are travelling on, an onboard server which controls the bogie units and a wireless network which enables communication between the server and the bogie units.
2. The system of claim 1 wherein the bogie units have sensors to monitor the temperature of the hub of a bogie wheel.
3. The system of claim 1 wherein the bogie units have sensors to monitor the temperature of the periphery of a bogie wheel.
4. The system of claim 1 wherein the bogie units have motion detectors to monitor movement of the bogie axle in vertical and horizontal directions.
5. The system of claim 1 wherein the bogie units have accelerometers to monitor acceleration of the bogie axle.
6. The system of claim 1 wherein the bogie units have means to measure the speed of rotation of a bogie wheel.
7. The system of claim 1 wherein the bogie units are powered by an electrical generator which utilises the rotation of the bogie wheels.
8. The system of claim 1 wherein the bogie units have a processor which compares the critical parameters against defined standards.
9. The system of claim 1 wherein the bogie units have a wireless transceiver which enables communication with other bogie units and the server.
10. The system of claim 1 wherein the bogie units have a source of illumination.
11. The system of claim 1 wherein the wireless network utilises master/slave base band role switching.
12. The system of claim 1 wherein the wireless network has store-and-forward nodes which convey quasi real time data to the server.
13. The system of claim 1 wherein the wireless network utilises frequency hopping modes.
14. The system of claim 1 wherein the server can download data to a wayside database.
15. The system of claim 1 which also has a GPS unit to record the location of the train at any time.
16. The system of claim 1 which has an end-of-train monitoring function.

BNSDOCID: <WO_____2005105536A1_I_>

17. The system of claim 1 which has a collision avoidance function.

18. The system of claim 1 which has a level crossing warning function.

19. The system of claim 1 which transmits a warning signal to vehicles approaching a level crossing which are equipped to receive said signal.

20. The system of claim 1 which monitors tension and compression in the train wagon couplings.

DATED THIS THIRD DAY OF MAY 2005

STI RAIL PTY LTD

BY THEIR PATENT ATTORNEY

IPFIRST

BNSDOCID: <WO_____2005105536A1_I_>

Figure 1

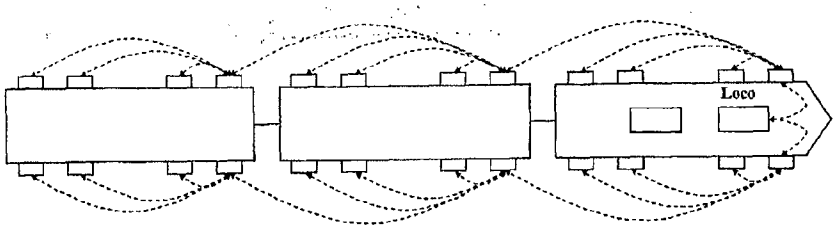
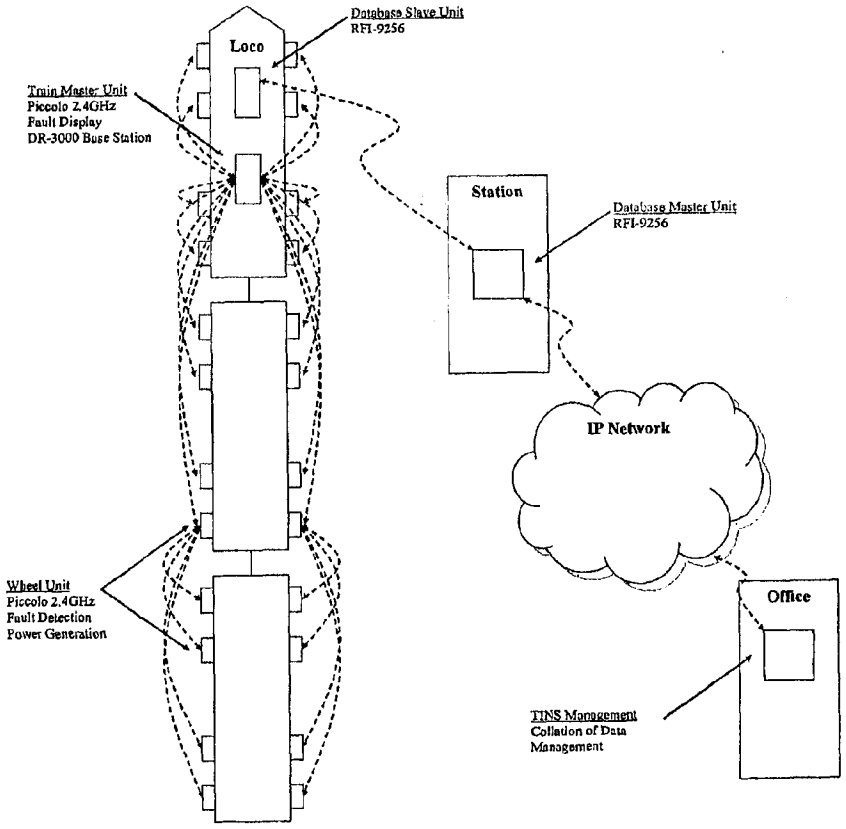


Figure 2



BNSDOCID: <WO_____2005105536A1_I_>

Figure 3

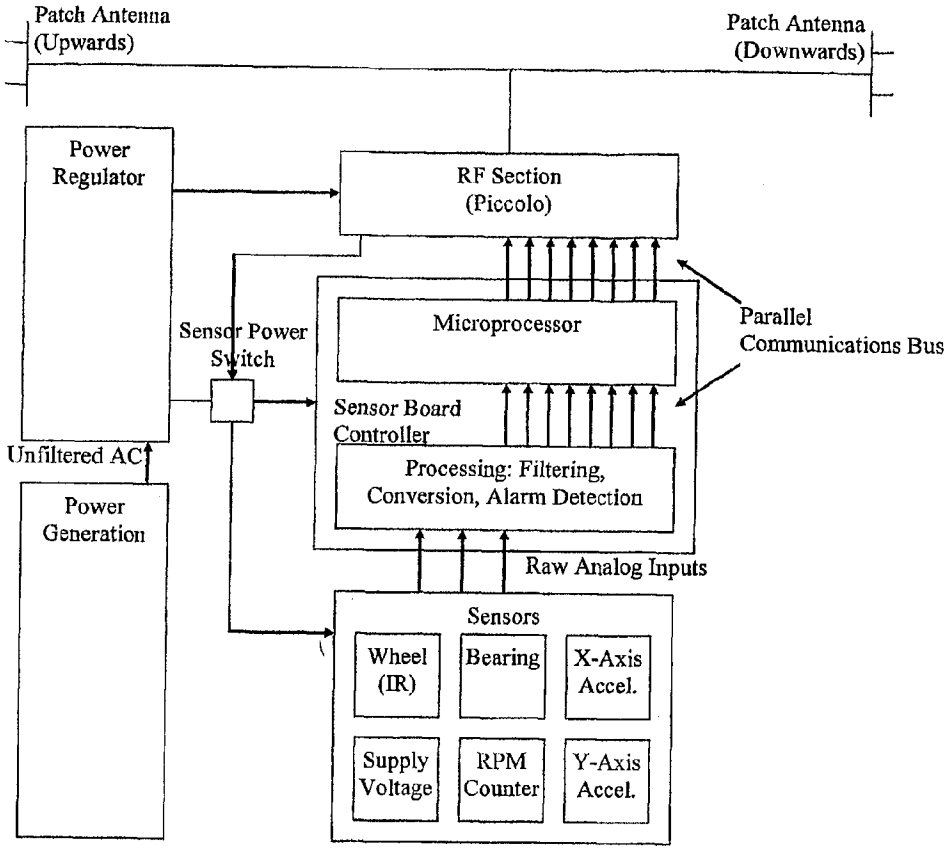
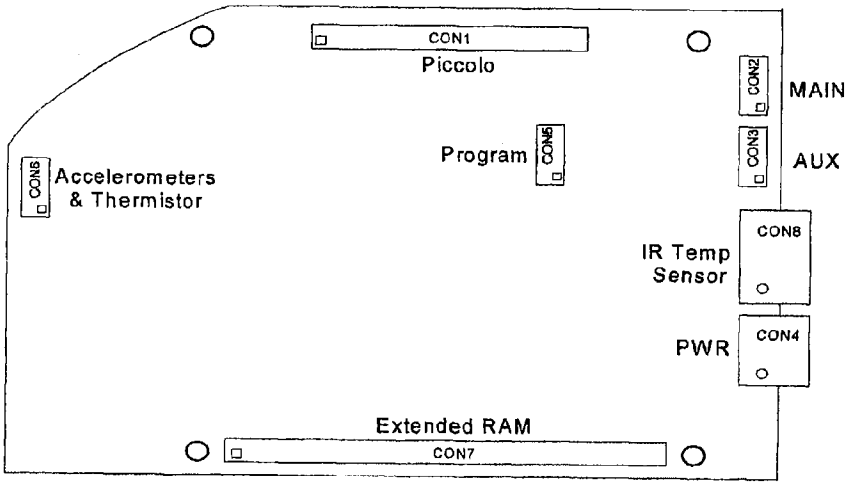


Figure 4



BNSDOCID: <WO_____2005105536A1_I_>

Figure 5

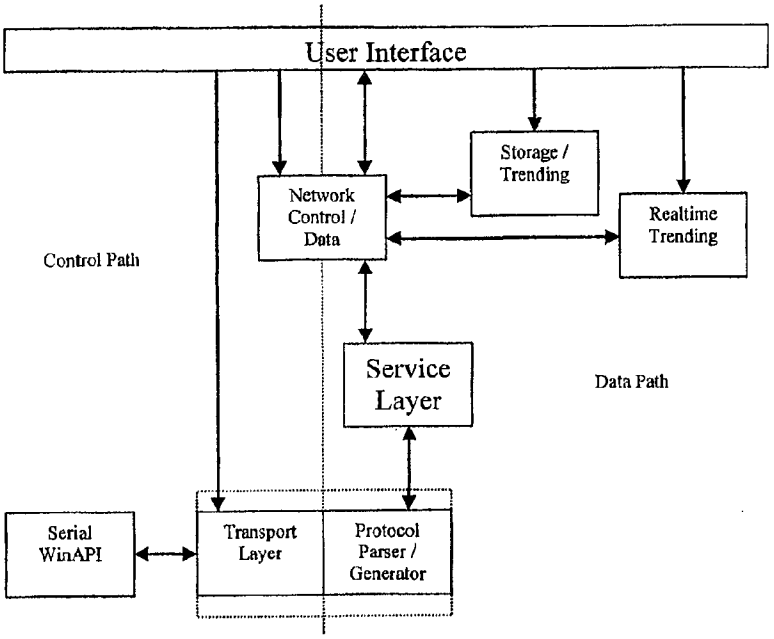


Figure 6

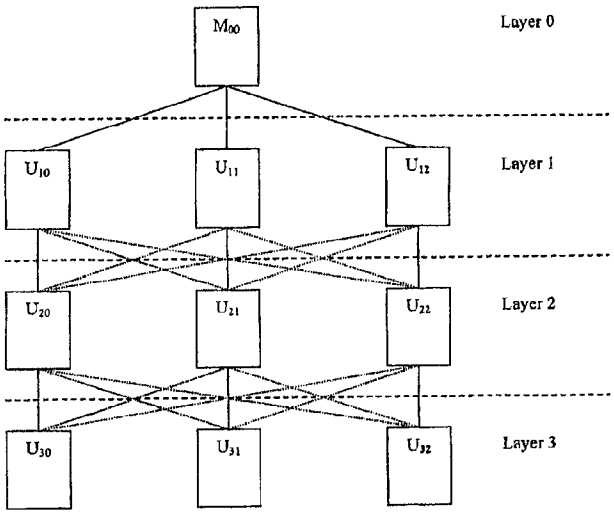


Figure 7

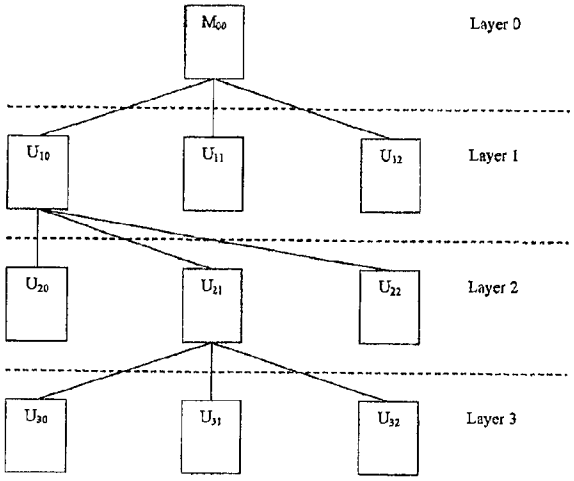
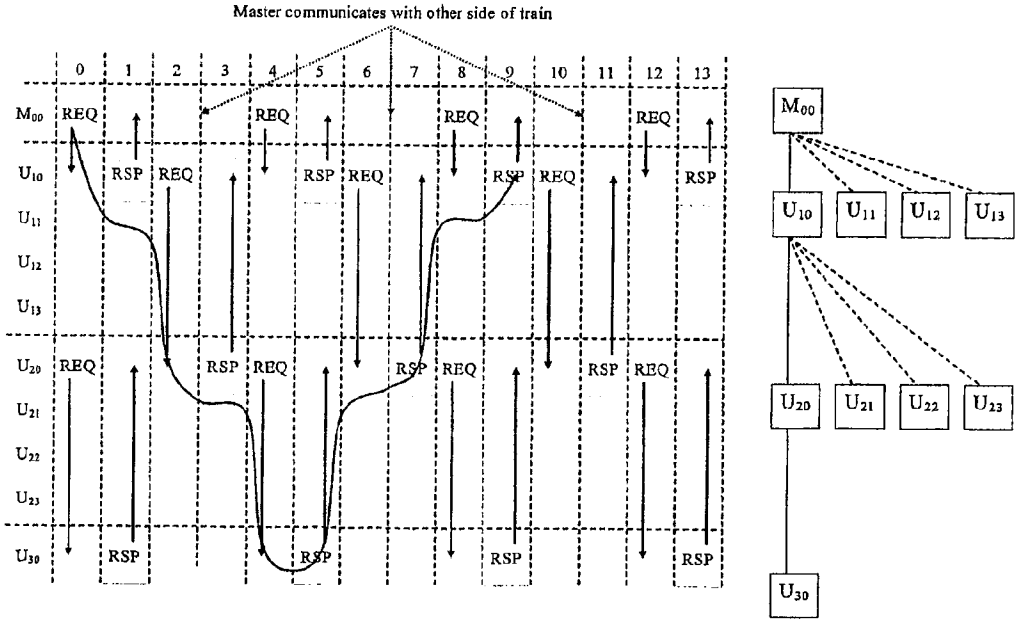
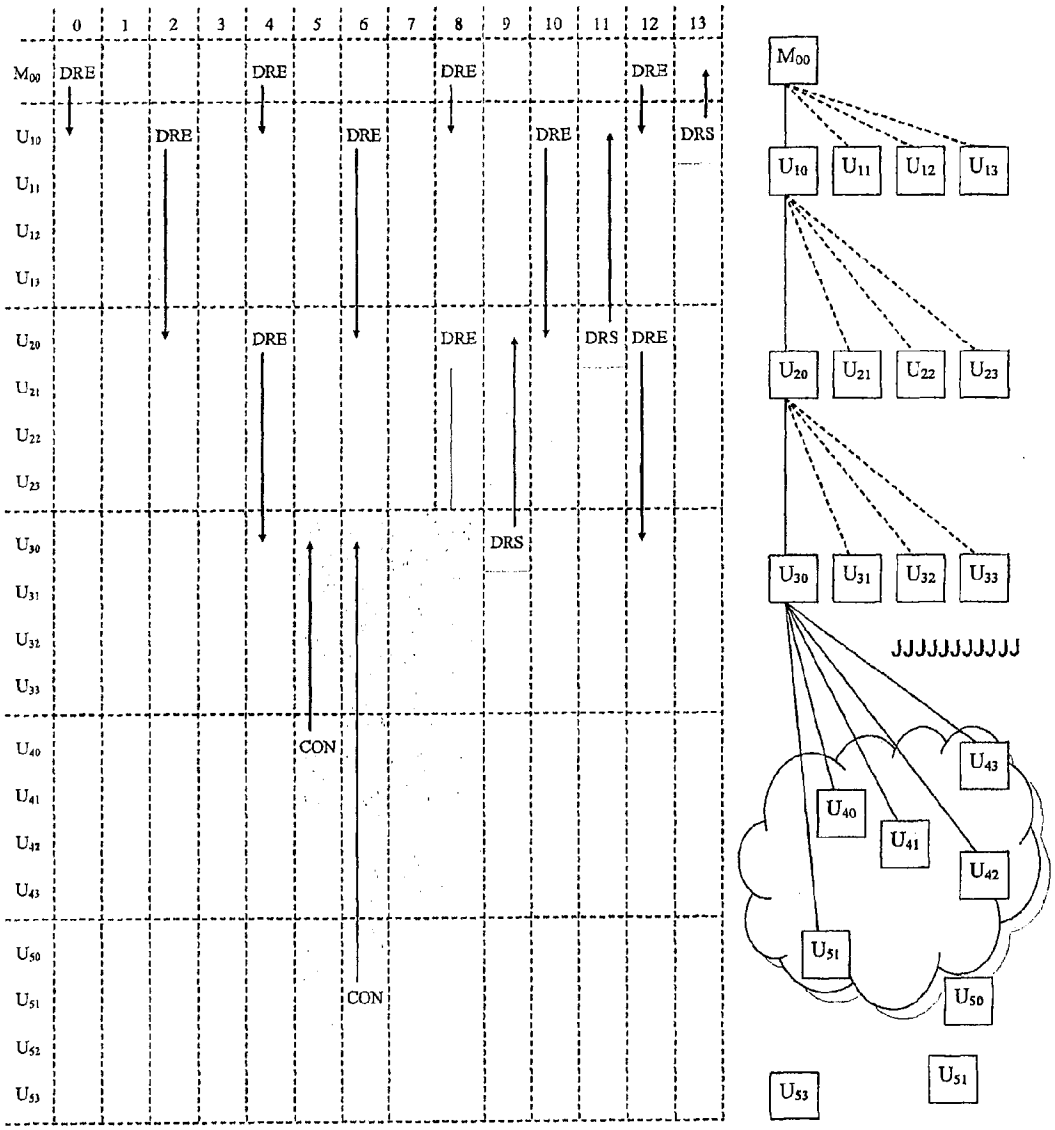


Figure 8



BNSDOCID: <WO_____2005105536A1_I_>

Figure 9



BNSDOCID: <WO_____2005105536A1_I_>

Figure 10

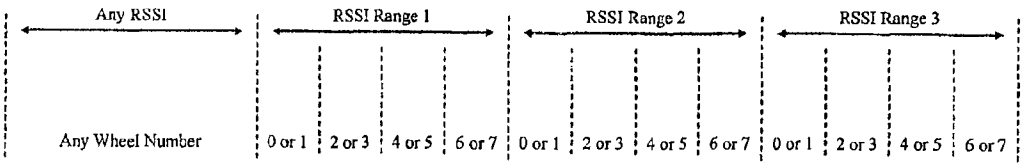
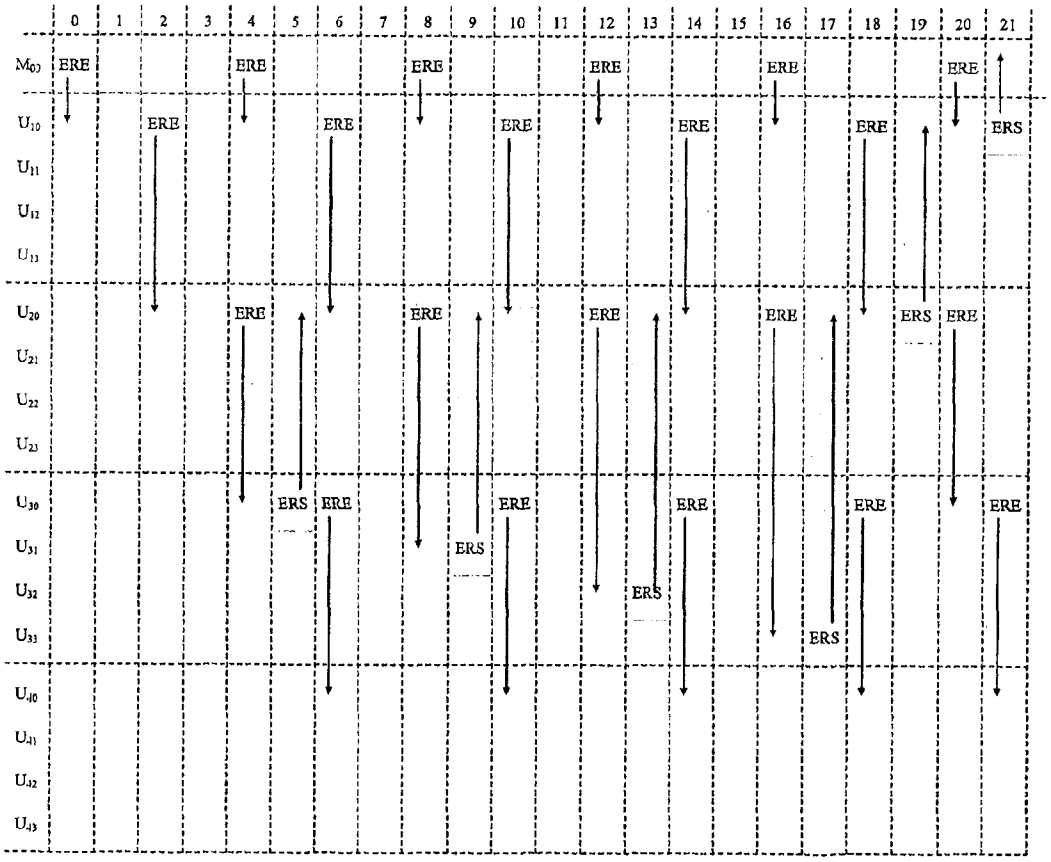
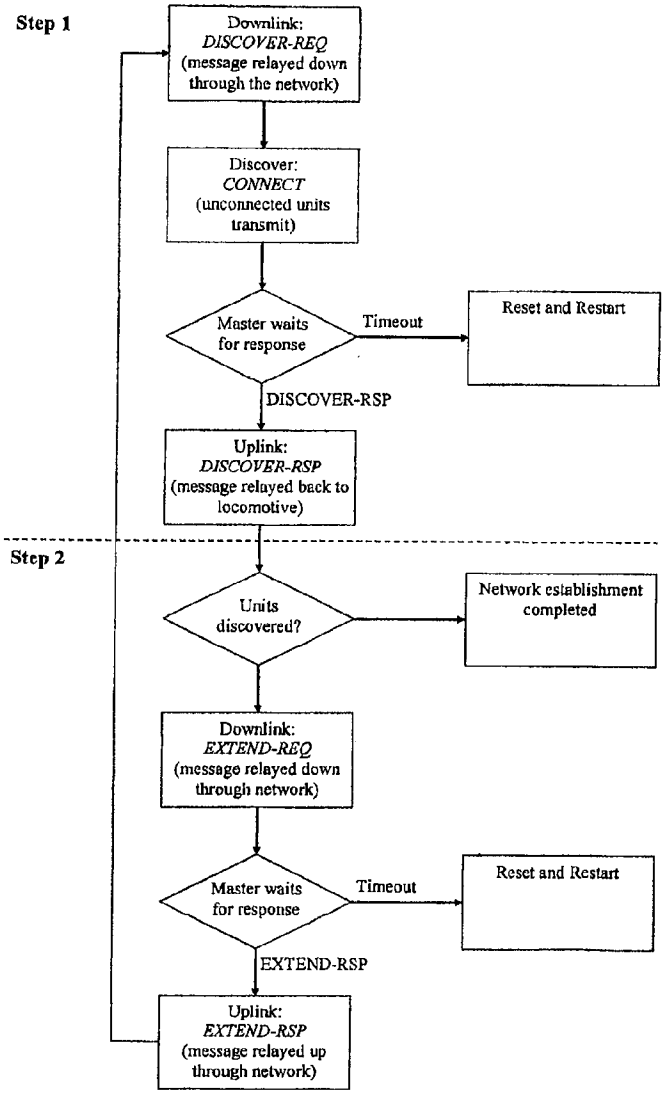


Figure 11



BNSDOCID: <WO 2005105536A1 >

Figure 12



BNSDOCID: <WO_____2005105536A1_I_>

Figure 13

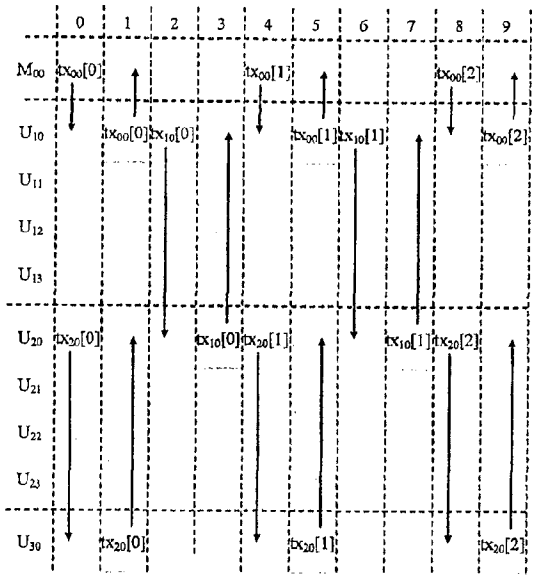
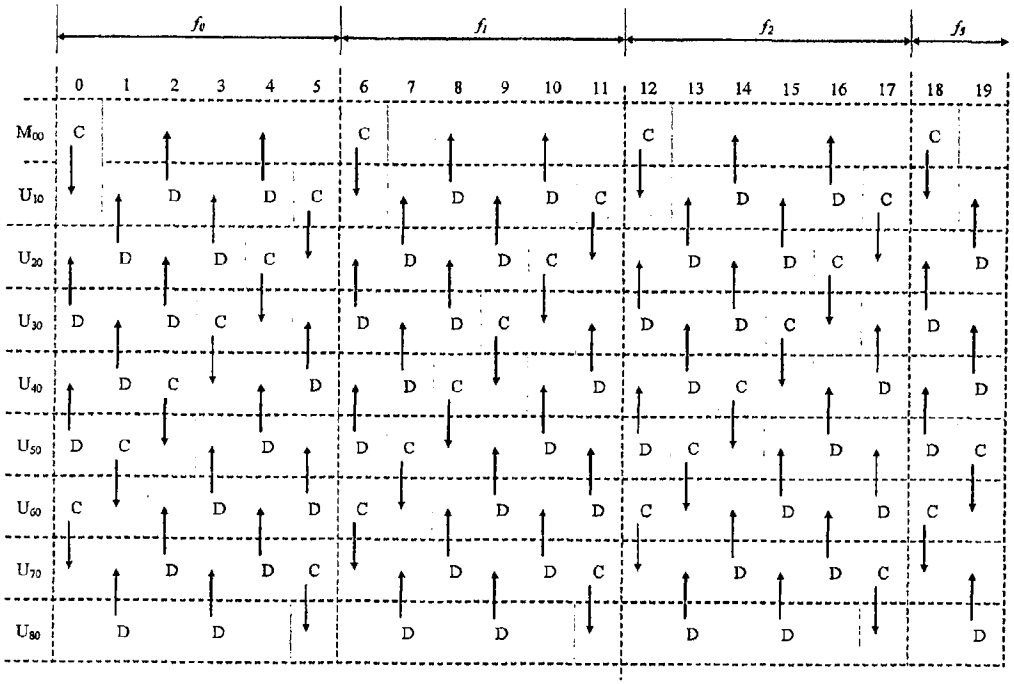
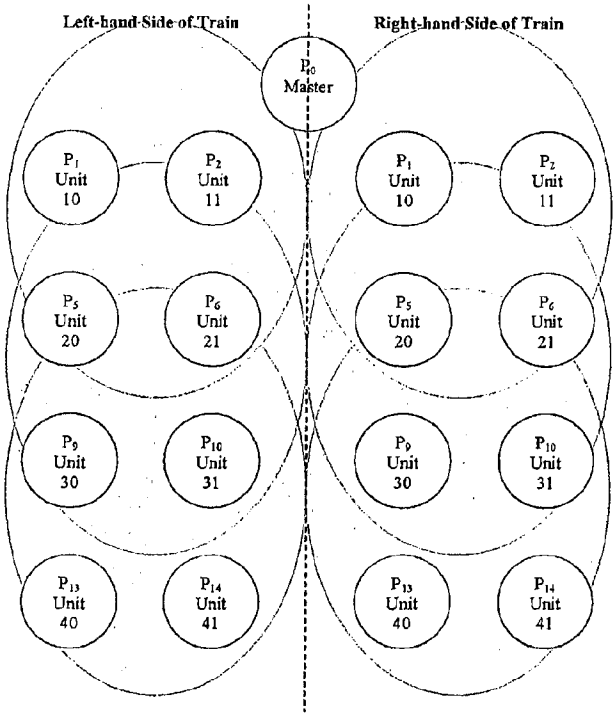


Figure 14



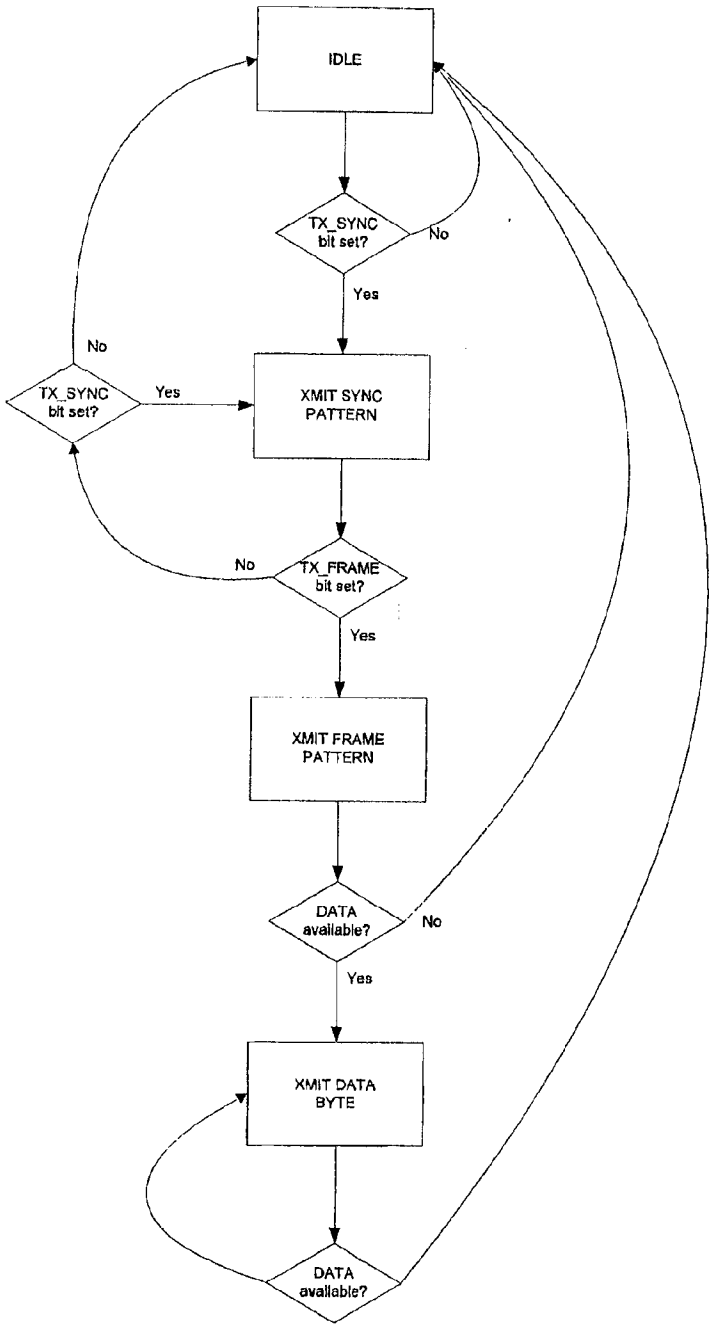
BNSDOCID: <WO_____2005105536A1_|_>

Figure 15



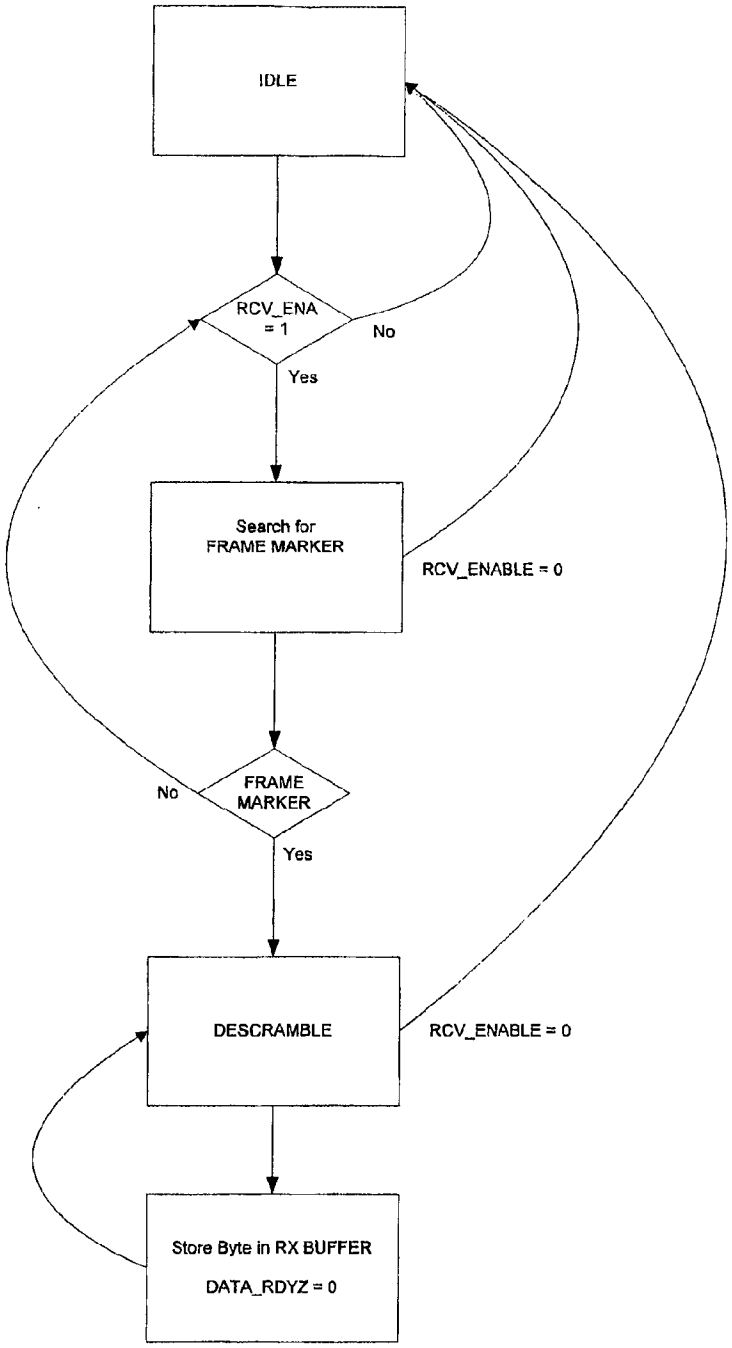
BNSDOCID: <WO_____2005105536A1_I_>

Figure 16



BNSDOCID: <WO_____2005105536A1_I_>

Figure 17



BNSDOCID: <WO_____2005105536A1_I_>

Figure 18

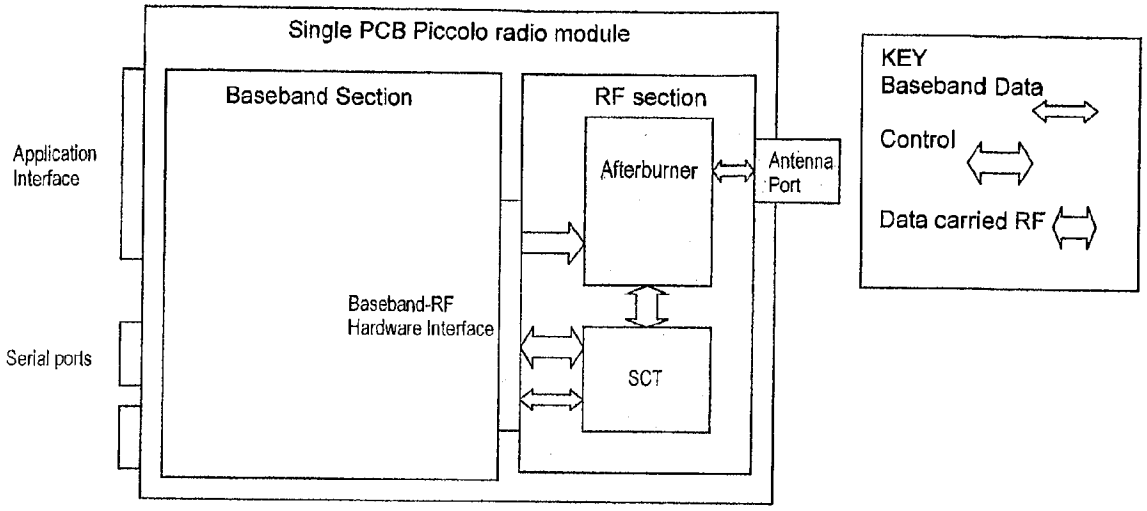
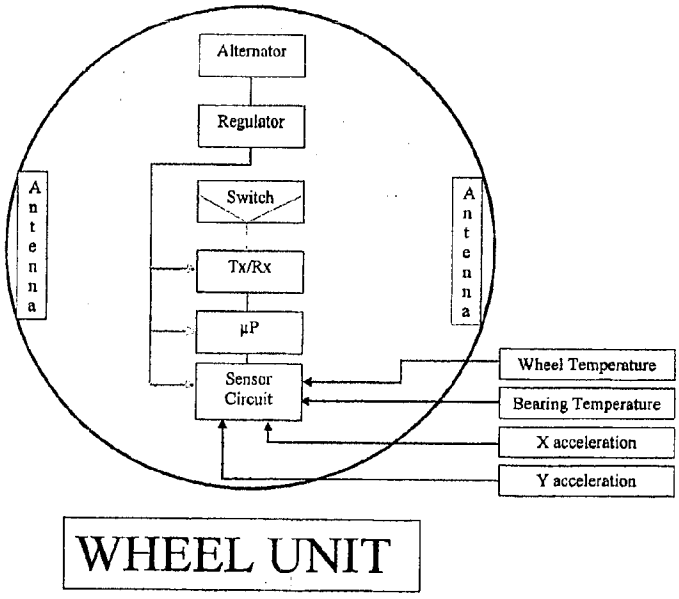


Figure 19



BNSDOCID: <WO_____2005105536A1_I_>

Figure 20

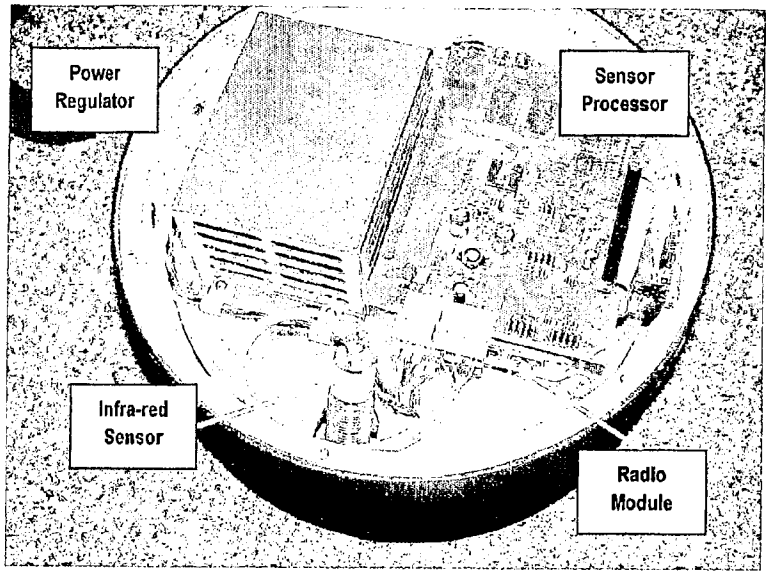


Figure 21

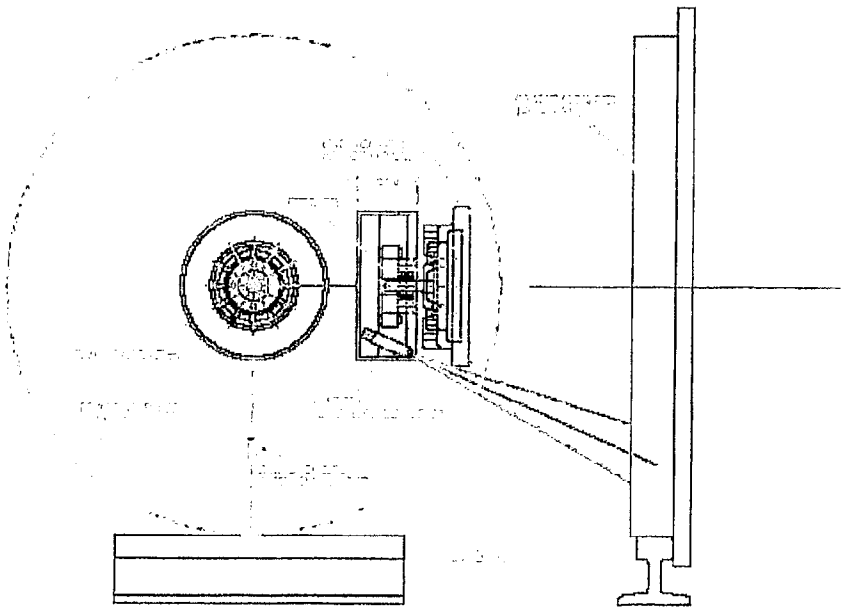
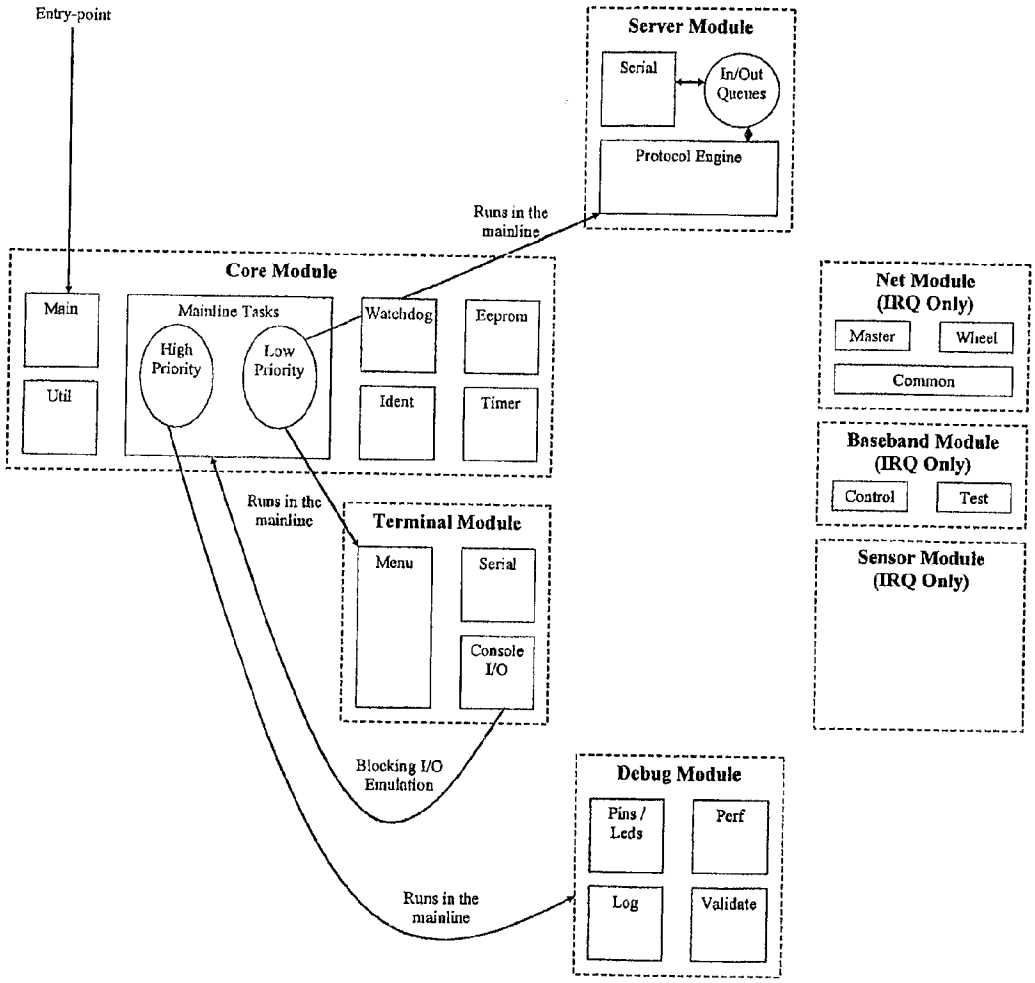


Figure 22



BNSDOCID: <WO_____2005105536A1_I_>

Electronic Acknowledgement Receipt

EFS ID:	30518425
Application Number:	15108065
International Application Number:	
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht/Natalie Ward
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	29-SEP-2017
Filing Date:	24-JUN-2016
Time Stamp:	12:40:19
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	updated_IDS_.pdf	1104947 66dd9724d5d737eace31224793ff84f2567ce2c1	no	7

Warnings:

Information:					
2	Foreign Reference	29895822_1_EP_1548419.pdf	6871212 0e5cbf9088631e549d0f64c0402bb791d2b548e4	no	103
Warnings:					
Information:					
3	Foreign Reference	P36736B_US_EP_2650191.pdf	365876 02fca8fe8598e6dc08c16025fca0caaa47bb6484	no	8
Warnings:					
Information:					
4	Foreign Reference	P36736B_US_JP_05213195.pdf	301238 b2e1e6537537c44bd72399bb8d0c9d5b6d9734df	no	9
Warnings:					
Information:					
5	Foreign Reference	P36736B_US_JP_05343294.pdf	1223677 5bb02f184427b5b4f808fc437a5fbb7a1652092b	no	22
Warnings:					
Information:					
6	Foreign Reference	P36736B_US_JP-08015099.pdf	359915 cd948f8107b2252d8a8cba1df8c0610ca1d3cb4a	no	8
Warnings:					
Information:					
7	Foreign Reference	P36736B_US_JP_10217968.pdf	524880 c5d1cac6105891f6fd7597849bfde4517ccd8ea9	no	9
Warnings:					
Information:					
8	Foreign Reference	P36736B_US_JP_11192948.pdf	876766 9a69c5387468553f2512338791ec0a98d0a3bd0d	no	14
Warnings:					
Information:					

9	Foreign Reference	WO_01015001_A2_.pdf	3893597 b43fe2207bf458e23757acd3bb5da6d7667997b9	no	50
Warnings:					
Information:					
10	Foreign Reference	WO_2005105536.pdf	2619218 a250b3dfc32a717e44357c5dc48eab7f343396b9	no	38
Warnings:					
Information:					
			Total Files Size (in bytes):	18141326	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	Art Unit
	JASON C SMITH	3617

CPC - Searched*		
Symbol	Date	Examiner
B60T 17/22	10/27/2017	jcs
B61L 15/00, 0018, 0027, 0054, 0072, 0081	10/27/2017	jcs
G01K 7/02	10/27/2017	kcs
G06F 19/00	10/27/2017	jcs
G08B 21/18	10/27/2017	jcs

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
east text search	10/27/2017	jcs

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner

/Jason C Smith/ Primary Examiner, Art Unit 3617	

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	"15108065"	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:13
L2	28	("20050259619" | "20060264221" | "20070241610" | "20080195265" | "20090001226" | "20090173840" | "20100200307" | "20110270475" | "20110282540" | "3718040" | "5446451" | "5603556" | "5682139" | "5691980" | "6175784" | "6184798" | "6301531" | "6339397" | "6668216" | "7336156" | "7688218" | "7698962" | "8244411" | "8370006" | "8672273" | "8751290" | "9365223" | "9663092").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:14
L3	1769	b60t17/22.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
L4	36	b61l15/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
L5	584	g01k7/02.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
L6	1843	g06f19/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
L7	2244	g08b21/18	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L8	116	246/129.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L9	3732	340/438.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L10	1338	340/870.16.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L11	737	340/870.17.ccls.	US-PGPUB;	OR	OFF	2017/10/27 16:19

			USPAT; USOCR			
L12	470	374/152.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L13	1525	701/19.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L14	543	701/20.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L15	725	b61l15/0027.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
L16	127	b61l15/0054.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
L17	342	b61l15/0072.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
L18	435	b61l15/0081.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
L19	59	b61l15/0018.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
L20	388	martin adj andrew.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
L21	42	cooper adj francis.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
L22	1	adamec adj rachel.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
L23	243	b61l27/0094.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
L24	83	b61k9/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
L25	295	b61k9/04.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21

L26	608	b61l25/021.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
L27	869	b61l25/025.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21

10/27/2017 4:22:10 PM
C:\Users\jsmith8\Documents\EAST\Workspaces\15108065.wsp

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 1019

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
15/108,065	06/24/2016	246	3617	P37056A US (37659.00060)

APPLICANTS

AMSTED RAIL COMPANY, INC., Chicago, IL;

INVENTORS

William LeFebvre, West Chester, PA;
Andrew Martin, West Chester, PA;
Francis James COOPER, Downingtown, PA;
Rachel W. ADAMEC, Norristown, PA;

**** CONTINUING DATA ***************************

This application is a 371 of PCT/US14/72380 12/24/2014
which claims benefit of 61/920,700 12/24/2013

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

07/28/2016

Foreign Priority claimed	35 USC 119(a-d) conditions met	Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ Yes ☑ No	☐ Yes ☑ No	/JASON C SMITH/ Examiner's Signature	☐ Initials	PA	14	31	4

ADDRESS

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648
UNITED STATES

TITLE

SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

FILING FEE RECEIVED		
2420	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. LeFebvre et al.
Art Unit	
Examiner Name	
Attorney Docket Number	037659.00060

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3718040		1973-02-27	Freeman et al.	
	2	5446451		1995-08-29	Grosskopf, Jr.	
	3	5603556		1997-02-18	Klink	
	4	5682139		1997-10-28	Pradeep et al.	
	5	5691980		1997-11-25	Welles, II et al.	
	6	6175784	B1	2001-01-16	Jicha et al.	
	7	6184798	B1	2001-02-06	Egri	
	8	6301531	B1	2001-10-09	Pierro et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. LeFebvre et al.
	Art Unit	
	Examiner Name	
	Attorney Docket Number	037659.00060

	9	6339397	B1	2002-01-15	Baker	
	10	6668216	B2	2003-12-23	Mays	
	11	7336156	B2	2008-02-26	Arita et al.	
	12	7688218	B2	2010-03-30	LeFebvre et al.	
	13	7698962	B2	2010-04-20	LeFebvre et al.	
	14	8244411	B2	2012-08-14	Baker	
	15	8370006	B2	2013-02-05	Kumar et al.	
	16	8672273	B2	2014-03-18	Brown et al.	
	17	8751290	B2	2014-06-10	Schullian et al.	
	18	9365223	B2	2014-06-14	Martin et al.	
	19	9663092	B2	2017-05-30	Martin et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. LeFebvre et al.
Art Unit	
Examiner Name	
Attorney Docket Number	037659.00060

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20090001226	A1	2009-01-01	Haygood	
	2	20100200307	A1	2010-08-12	Toms	
	3	20050259619	A1	2005-11-24	Boettle et al.	
	4	20060264221	A1	2006-11-23	Koike et al.	
	5	20070241610	A1	2007-10-18	Smith	
	6	20080195265	A1	2008-08-14	Searle et al.	
	7	20090173840	A1	2009-07-09	Brown et al.	
	8	20110270475	A1	2011-11-03	Brand et al.	
	9	20110282540	A1	2011-11-17	Armitage et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. LeFebvre et al.
Art Unit	
Examiner Name	
Attorney Docket Number	037659.00060

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	1548419	EP	A1	2005-06-29	NSK Ltd.		
	2	2650191	EP	A1	2013-10-16	Progress Rail Services Corporation		
	3	05213195	JP	A	1993-08-24	Sumitomo Metal Ind Ltd		
	4	05343294	JP		1993-12-24	NEC Corp		
	5	08015099	JP		1996-01-19	Sumitomo Metal Ind Ltd		
	6	10217968	JP		1998-08-18	Toshiba Corp		
	7	11192948	JP		1999-07-21	Toshiba Corp		
	8	2001015001	WO	A2	2001-01-03	General Electric Company		
	9	2005105536	WO	A1	2005-10-11	Sti Rail Pty Ltd		

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. LeFebvre et al.
Art Unit	
Examiner Name	
Attorney Docket Number	037659.00060

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature	/Jason C Smith/	Date Considered	10/27/2017

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. LeFebvre et al.
Art Unit	
Examiner Name	
Attorney Docket Number	037659.00060

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2017-09-29
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

29880 7590 11/01/2017

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
SMITH, JASON C	

ART UNIT	PAPER NUMBER
3617	

NOTIFICATION DATE	DELIVERY MODE
11/01/2017	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocket@foxrothschild.com

Office Action Summary	Application No. 15/108,065	Applicant(s) LeFebvre et al.	
	Examiner JASON C SMITH	Art Unit 3617	AIA Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☑ Responsive to communication(s) filed on 06/24/2016 .

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____ .

2a)☐ This action is **FINAL.** 2b) ☑ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☑ Claim(s) 1-65 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☑ Claim(s) 1-50,54 and 60-65 is/are rejected.

8)☑ Claim(s) 51-53 and 55 is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☑ The drawing(s) filed on 24 June 2016 is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____ .

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☑ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date 09/29/2017 .

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____ .

4) ☐ Other: _____ .

DETAILED CORRESPONDENCE

Information Disclosure Statement

The information disclosure statement (IDS) submitted on 09/29/2017 is being considered by the examiner.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a)(1) the claimed invention was patented, described in a printed publication, or in public use, on sale or otherwise available to the public before the effective filing date of the claimed invention.

Claim(s) 1-30, 33-44, 46, 48-50, 54, and 60-65 is/are rejected under 35 U.S.C. 102a1 as being anticipated by LeFebvre et al. (7,668,218). Regarding claim 1, LeFebvre discloses a system for detecting operational anomalies on a train consist or railcar (abstract, regarding the system communicates signals of critical departures and car identity to a remote source) comprising: a) one or more communication management units (data control unit 23; fig. 1) mounted on one or more railcars (railroad freight car 22; fig. 1); b) one or more sensors (col. 3, line 65, regarding pads 16 with their associated sensors 5; fig. 3) located on said one or more railcars (col. 3, line 67, regarding each truck 1 carries four pads 16; figs. 1 and 2) for sensing an operational parameter of said one or more railcars (col. 5, lines 41-44, regarding the instrumented pads 16 contain several sensors for measurement of dynamic and static vertical loads and shear or lateral forces), said sensors (sensors 5; fig. 3) being in communication with said one or more communication management units (col. 4, lines 5-7, regarding the data control unit 23 has a radio/receiver which has the ability to communicate with the radios on the pads 16); and c) wherein said communication management units (data control unit 23) perform the functions of: i) collecting data

regarding said one or more railcar operational parameters (col. 6, lines 11-12, regarding the data control unit 23 is an aggregator of information); ii) analyzing said collected data for trends or events indicative of an anomalous operational condition (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment); and iii) communicating a message to a remote receiver when said trend or event is detected (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive).

Regarding claim 2, LeFebvre discloses the invention in claim 1, and LeFebvre further discloses the invention further comprising one or more wireless sensor nodes (instrumented pads 16) in communication with one of said communication management units (col. 4, lines 5-7, regarding the data control unit 23 has a radio/receiver which has the ability to communicate with the radios on the pads 16), said one or more sensors (5) forming part of said one or more wireless sensor nodes (col. 3, lines 33-34, regarding the pad 16 contains a plurality of sensors 5; fig. 3).

Regarding claim 3, LeFebvre discloses the invention in claim 2, and LeFebvre further discloses wherein each of said wireless sensor nodes (instrumented pads 16) performs the functions of: a) collecting data from one or more sensors (col. 8, lines 52-54, regarding the microprocessors 19 at the instrumented pads 16 take a series of measurements and treat them as a time series; fig. 3); b) comparing said data against one or more rules (col. 8, lines 54-57, regarding the search algorithms can identify periodicities and cross correlations in and between time series so that any behavior detectable at pad level will be seen); and c) sending a message to said communication management unit (data control unit 23) when at least one of said rules is satisfied (col. 9, lines 4-7, regarding if such behavior is inferred at the

instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23).

Regarding claim 4, LeFebvre discloses the invention in claim 2, and LeFebvre further discloses wherein each of said wireless sensor nodes (instrumented pad 16) performs the functions of; a) collecting data from one or more sensors (col. 8, lines 52-54, regarding the microprocessors 19 at the instrumented pads 16 take a series of measurements and treat them as a time series; fig. 3); and b) periodically sending said collected data to said communication management unit (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23).

Regarding claim 5, LeFebvre discloses the invention in claim 3, and LeFebvre further discloses wherein said one or more rules are numerical thresholds which, when exceeded by said collected data, cause an alert message to be sent to said communication management unit (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23).

Regarding claim 6, LeFebvre discloses the invention in claim 5, and LeFebvre further discloses wherein said data is acceleration data (col. 13, lines 12-13, regarding the commands can be influenced by the measured accelerations at the data control unit 23).

Regarding claim 7, LeFebvre discloses the invention in claim 5, and LeFebvre further discloses wherein said data is temperature data (col. 12, lines 45-50, regarding the data control unit 23 instructs the pads 16 to measure temperatures).

Regarding claim 8, LeFebvre discloses the invention in claim 5, and LeFebvre further discloses wherein said communication management unit (data control unit 23), upon receiving an alert message from one of said wireless sensor nodes (instrumented pads 16), performs the functions of: a) waiting to see if similar messages are received from one or more other wireless sensor nodes (instrumented pads 16) within a predetermined period of time and concluding that an actual event has occurred if said similar messages are received (col. 9, lines 45-46, regarding looking for a higher frequency and a similar signal from both wheels in the wheel set); and b) communicating a message reporting the occurrence of said actual event to a remote receiver (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive).

Regarding claim 9, LeFebvre discloses the invention in claim 4, and LeFebvre further discloses wherein said communication management unit (data control unit 23), upon receiving said periodically sent data (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23), performs the functions of: a) storing said data in a data store (col. 11, lines 10-11, regarding pad 16 data is recorded in the data control unit 23 in non-volatile memory); b) analyzing said stored data for trends (col. 6, lines 12-17, regarding the data control unit 23 uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment); and c) generating a report when trends of interest are detected (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive).

Regarding claim 10, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said wireless sensor node (instrumented pad 16) is mounted (as shown in fig. 4) on the wheel bearing

(bearing adapters 4; fig. 4) fitting of a railcar (railroad freight car 22) and wherein said data is analyzed to see if acceleration thresholds (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23) representing one or more of the following have been exceeded: wheel damage, vertical impacts or derailment (col. 6, lines 12-17, regarding the data control unit 23 uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment).

Regarding claim 11, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said wireless sensor node (instrumented pad 16) is mounted (as shown in fig. 4) on the body of a railcar (railroad freight car 22) and further wherein said data is analyzed to see if acceleration thresholds (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23) representing one or more of the following have been exceeded: vertical hunting, lateral hunting, vertical extreme vehicle dynamics, lateral extreme vehicle dynamics, or longitudinal impacts (col. 9, lines 55-56, regarding truck and axle hunting can be identified).

Regarding claim 12, LeFebvre discloses the invention in claim 7, and LeFebvre further discloses wherein said wireless sensor node (instrumented pad 16) is mounted (as shown in fig. 4) on the wheel bearing fitting (bearing adapter 4) of a railcar (railroad freight car 22) and wherein said data is analyzed to see if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 13, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said communication management unit (data control unit 23) confirms that a derailment event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when derail messages have been received from a plurality of wireless sensors nodes (instrumented pads 16) within said predetermined period of time (col. 9, lines 45-46, regarding looking for a higher frequency and a similar signal from both wheels in the wheel set).

Regarding claim 14, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said communication management unit (data control unit 23) confirms that vertical hunting is occurring when vertical hunting messages are received from wireless sensor nodes (instrumented pads 16) mounted on opposite ends of a railcar (railroad freight car 22) within a predetermined period of time (col. 9, lines 49-54, regarding using load sensors mounted in the instrumented pad 16 on both wheel sets on a truck to detect longitudinal, lateral and yawing forces and monitor rapidly changing loads).

Regarding claim 15, LeFebvre discloses the invention in claim 14, and LeFebvre further discloses wherein said communication management unit (data control unit 23) determines that a body bounce event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when messages from said wireless sensor nodes (instrumented pads 16) indicate that vertical hunting messages received from said wireless sensor nodes (instrumented pads 16) indicate in phase accelerations were detected (col. 8, lines 63-66, regarding these irregularities in behavior will be apparent in the changing load and distribution of load in the instrumented pad 16, which can sense vertical, shear and braking forces).

Regarding claim 16, LeFebvre discloses the invention in claim 14, and LeFebvre further discloses wherein said communication management unit (data control unit 23) determines that a body pitch event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when messages from said wireless sensor nodes (instrumented pads 16) indicate that vertical hunting messages received from said wireless sensor nodes (instrumented pads 16) indicate out of phase accelerations were detected (col. 8, lines 63-66, regarding these irregularities in behavior will be apparent in the changing load and distribution of load in the instrumented pad 16, which can sense vertical, shear and braking forces).

Regarding claim 17, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said communication management unit (data control unit 23) confirms that a lateral extreme vehicle dynamic event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when lateral extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes (instrumented pads 16) within said predetermined period of time (col. 9, lines 49-54, regarding using load sensors mounted in the instrumented pad 16 on both wheel sets on a truck to detect longitudinal, lateral and yawing forces and monitor rapidly changing loads).

Regarding claim 18, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said communication management unit (data control unit 23) confirms that a vertical extreme vehicle dynamic event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when vertical extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes (instrumented pads 16) within said predetermined period of time (col. 9, lines 49-54, regarding

using load sensors mounted in the instrumented pad 16 on both wheel sets on a truck to detect longitudinal, lateral and yawing forces and monitor rapidly changing loads).

Regarding claim 19, LeFebvre discloses the invention in claim 8, and LeFebvre further discloses wherein said communication management unit (data control unit 23) confirms that lateral hunting is occurring (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when lateral hunting messages are received from wireless sensor nodes (instrumented pads 16) mounted on opposite ends of a railcar (railroad freight car 22) within a predetermined period of time (col. 9, lines 49-54, regarding using load sensors mounted in the instrumented pad 16 on both wheel sets on a truck to detect longitudinal, lateral and yawing forces and monitor rapidly changing loads).

Regarding claim 20, LeFebvre discloses the invention in claim 19, and LeFebvre further discloses wherein said communication management unit (data control unit 23) determines that a body yaw event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) when messages from said wireless sensor nodes (instrumented pads 16) indicate that lateral hunting messages received from said wireless sensor nodes (instrumented pads) indicate out of phase accelerations were detected (col. 8, lines 63-66, regarding these irregularities in behavior will be apparent in the changing load and distribution of load in the instrumented pad 16, which can sense vertical, shear and braking forces).

Regarding claim 21, LeFebvre discloses the invention in claim 19, and LeFebvre further discloses wherein said communication management unit (data control unit 23) determines that a body roll event has occurred (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify

unsatisfactory behavior such as swaying, bouncing or even partial derailment) when messages from said wireless sensor nodes (instrumented pads 16) indicate that lateral hunting messages received from said wireless sensor nodes (instrumented pads 16) indicate in phase accelerations were detected (col. 8, lines 63-66, regarding these irregularities in behavior will be apparent in the changing load and distribution of load in the instrumented pad 16, which can sense vertical, shear and braking forces).

Regarding claim 22, LeFebvre discloses the invention in claim 7, and LeFebvre further discloses wherein said wireless sensor node (instrumented pad 16) is mounted (as shown in fig. 4) on the wheel bearing (bearing adapter 4) fitting of a railcar (railroad freight car 22) and wherein said data is analyzed to determine if a temperature threshold representing absolute temperature or temperature above ambient have been exceeded (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 23, LeFebvre discloses the invention in claim 4, and LeFebvre further discloses wherein said data is temperature data (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 24, LeFebvre discloses the invention in claim 3, and LeFebvre further discloses wherein said wireless sensor nodes (instrumented pads 16) are mounted (as shown in fig. 4) on wheel bearing fittings (bearing adapters 4) of a railcar (railroad freight car 22) on opposite sides of a same axle (as shown in fig. 2), and wherein said communication management unit (data control unit 23) generates a differential temperature alert (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive) when temperatures reported by said wireless sensor nodes (instrumented pads 16) on said opposite sides of

said axle exceed a differential threshold (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 25, LeFebvre discloses the invention in claim 23, and LeFebvre further discloses wherein said communication management unit (data control unit 23) generates an alert (col. 9, lines 12-13, regarding when serious trouble is inferred by the data Control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive) if greater than a certain percentage of the temperature readings received exceed an absolute temperature threshold or an above ambient temperature threshold (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 26, LeFebvre discloses the invention in claim 23, and LeFebvre further discloses wherein said communication management unit (data control unit 23) generates an alert (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive) if greater than a certain percentage'of temperature readings indicate a temperature rise rate exceeding a certain threshold (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 27, LeFebvre discloses the invention in claim 3, and LeFebvre further discloses wherein said communication management unit (data control unit 23) can instruct each wireless sensor node (instrumented pad 16) to enable or disable the checking of individual rules by sending a message to said wireless sensor node (col. 12, lines 45-47, regarding the data control unit 23 instructs the pads 16 as to which data acquisition task to carry out and when to report back).

Regarding claim 28, LeFebvre discloses the invention in claim 4, and LeFebvre further discloses wherein said communication management unit (data control unit 23) can instruct each wireless sensor node (instrumented pad 16) to enable or disable the periodic sending of data by sending a message to said wireless sensor node (col. 12, lines 45-47, regarding the data control unit 23 instructs the pads 16 as to which data acquisition task to carry out and when to report back).

Regarding claim 29, LeFebvre discloses the invention in claim 3, and LeFebvre further discloses wherein each communication management unit (data control unit 23) in communication with one or more wireless sensor nodes (instrumented pad 16) form a railcar-based mesh network (col. 5, lines 26-28, regarding the instrumented pads 16 and data control units 23 establish a network of connections without external intervention) comprising said communication management unit (data control unit 23) and said wireless sensor nodes (instrumented pads 16), said railcar-based mesh network (col. 5, lines 26-28, regarding the instrumented pads 16 and data control units 23 establish a network of connections without external intervention) being controlled by said communication management unit (col. 6, lines 9-11, regarding the data control unit 23 coordinates the timing of the cyclic testing performed by the instrumented pad microprocessor and the timing of the messages issuing therefrom).

Regarding claim 30, LeFebvre discloses the invention in claim 29, and LeFebvre further discloses wherein said communication management unit (data control unit 23) includes wireless sensor nodes (instrumented pads 16) from other railcars in its railcar-based mesh network (col. 7, lines 12-14, regarding it would be feasible to let the instrumented pads 16 communicate along the train, passing messages from one freight car to the next).

Regarding claim 33, LeFebvre discloses the invention in claim 1, and LeFebvre further discloses wherein said remote receiver is located off-train (col. 4, lines 22-24, regarding communication may be via track side automatic equipment identification means or to a cellular or satellite radio system).

Regarding claim 34, LeFebvre discloses the invention in claim 33, and LeFebvre further discloses wherein said communication management unit (data control unit 23) communicates with said off-train remote receiver via a communication means comprising one of cellular, satellite, WiFi and Bluetooth (col. 4, lines 22-24, regarding communication may be via track side automatic equipment identification means or to a cellular or satellite radio system).

Regarding claim 35, LeFebvre discloses a system for detecting operational anomalies on a train consist or railcar (abstract, regarding the system communicates signals of critical departures and car identity to a remote source) comprising the steps of: a) collecting data regarding said one or more railcar operational parameters (col. 6, lines 11-12, regarding the data control unit 23 is an aggregator of information); b) analyzing said collected data for trends or events indicative of an anomalous operational condition (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment); and c) communicating a message to a remote receiver when said trend or event is detected (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive).

Regarding claim 36, LeFebvre discloses the invention in claim 35, and LeFebvre further discloses wherein steps (a) - (c) are performed by a communication management unit (data control unit 23) located on a railcar (railroad freight car 22) in said train consist (as shown in fig. 1).

Regarding claim 37, LeFebvre discloses the invention in claim 36, and LeFebvre further discloses wherein said data is collected from one or more wireless sensor nodes (instrumented pads 16) on said railcar (railroad freight car 22), said wireless sensor nodes (instrumented pads 16) being in communication with said communication management unit (col. 4, lines 5-7, regarding the data control unit 23 has a radio/receiver which has the ability to communicate with the radios on the pads 16).

Regarding claim 38, LeFebvre discloses the invention in claim 37, and LeFebvre further discloses wherein said communication management unit (data control unit 23) and said one or more wireless sensor nodes (instrumented pads 16) form a railcar-based mesh network (col. 5, lines 26-28, regarding the instrumented pads 16 and data control units 23 establish a network of connections without external intervention).

Regarding claim 39, LeFebvre discloses the invention in claim 37, and LeFebvre further discloses wherein said wireless sensor nodes (instrumented pads 16) each perform the functions of: a) collecting data from one or more sensors (col. 8, lines 52-54, regarding the microprocessors 19 at the instrumented pads 16 take a series of measurements and treat them as a time series; fig. 3); b) comparing said data against one or more rules (col. 8, lines 54-57, regarding the search algorithms can identify periodicities and cross correlations in and between time series so that any behavior detectable at pad level will be seen); and c) sending a message to said communication management unit (data control unit 23) when at least one of said rules is satisfied (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23).

Regarding claim 40, LeFebvre discloses the invention in claim 39, and LeFebvre further discloses wherein said one or more rules causes data collected from some sensors (5) to be periodically sent to said communication management unit (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23).

Regarding claim 41, LeFebvre discloses the invention in claim 39, and LeFebvre further discloses wherein said data includes one or more of the following: acceleration data (col. 13, lines 12-13, regarding the commands can be influenced by the measured accelerations at the data control unit 23) and temperature data (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 42, LeFebvre discloses the invention in claim 37, and LeFebvre further discloses wherein said communication management unit (data control unit 23) coordinates messages from two or more wireless sensor nodes (instrumented pads 16) to confirm that an event has occurred (col. 6, lines 12-14, regarding the data control unit 23 is programmed to compare information from all of the trucks on the railcar and draws inferences from them as to the status of the car).

Regarding claim 43, LeFebvre discloses the invention in claim 42, and LeFebvre further discloses wherein acceleration events are selected from a group consisting of wheel damage, vertical impact, derailment, vertical hunting, lateral hunting and longitudinal impact (col. 9, lines 55-56, regarding truck and axle hunting can be identified).

Regarding claim 44, LeFebvre discloses the invention in claim 42, and LeFebvre further discloses wherein temperature events include one or more of the following absolute temperature alarm, above ambient

temperature alarm, differential temperature alarm, peak analysis alarm, ambient analysis alarm and rate analysis alarm (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 46, LeFebvre discloses the invention in claim 35, and LeFebvre further discloses wherein said remote receiver is off-train (col. 4, lines 22-24, regarding communication may be via track side automatic equipment identification means or to a cellular or satellite radio system).

Regarding claim 48, LeFebvre discloses the invention in claim 1, and LeFebvre further discloses wherein at least one of said communication management units (data control unit 23) includes at least one of said sensors (col. 6, lines 25-27, regarding detectors of factors such as ambient temperature and humidity can be built into the data control unit 23).

Regarding claim 49, LeFebvre discloses the invention in claim 3, and LeFebvre further discloses wherein one of said wireless sensor nodes (instrumented pads 16) comprises: a) a protective housing (as shown in fig. 4); b) said one or more sensors (5) mounted within said protective housing (col. 3, lines 33-34, regarding the instrumented pad contains a plurality of sensors 5; fig. 3); c) a communication capability (communications unit 20; fig. 3), for communicating with said communication management unit (col. 4, lines 5-7, regarding the data control unit 23 has a radio/receiver which has the ability to communicate with the radios on the pads 16); and d) a microprocessor (microprocessor unit 19; fig. 3), executing firmware to control the operation of said wireless sensor node (col. 8, lines 52-54, regarding the microprocessors 19 at the instrumented pads 16 take a series of measurements and treat them as a time series; fig. 3).

Regarding claim 50, LeFebvre discloses the invention in claim 49, and LeFebvre further discloses wherein said one or more sensors (5) includes a sensor to measure accelerations (col. 5, lines 41-43, regarding the instrumented pads 16 contains several sensors for measurement of dynamic and static vertical loads) and wherein said wireless sensor node (instrumented pad 16) is tuned to detect certain types of accelerations (col. 8, lines 63-66, regarding these irregularities in behavior will be apparent in the changing load and distribution of load in the instrumented pad 16, which can sense vertical, shear and braking forces).

Regarding claim 54, LeFebvre discloses the invention in claim 49, and LeFebvre further discloses wherein said firmware performs the functions of: a) reading data from said one or more sensors (col. 8, lines 52-54, regarding the microprocessors 19 at the instrumented pads 16 take a series of measurements and treat them as a time series; fig. 3); b) comparing said data against a set of rules for reporting alerts or events (col. 8, lines 54-57, regarding the search algorithms can identify periodicities and cross correlations in and between time series so that any behavior detectable at pad level will be seen); and c) communicating an alert or event to said communication management unit (data control unit 23) when said data meets one or more of said rules (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing passed to the car's data control unit 23).

Regarding claim 60, LeFebvre discloses a system for detecting operational anomalies on a railcar that is part of a train consist (abstract, regarding the system communicates signals of critical departures and car identity to a remote source) comprising: a. at least one communication management unit (data control unit 23) mounted (as shown in fig. 4) on the train consist (railroad freight car 22); b. at least two sensors (5) located on the railcar (railroad freight car 22) for sensing operational parameters of the

railcar (col. 5, lines 41-44, regarding the instrumented pads 16 contain several sensors for measurement of dynamic and static vertical loads and shear or lateral forces), said sensors (5) being in communication with said CMU (col. 4, lines 5-7, regarding the data control unit 23 has a radio/receiver which has the ability to communicate with the radios on the pads 16); c. wherein said CMU (data control unit 23) performs the following functions: i) receiving data from said sensors (col. 9, lines 4-7, regarding if such behavior is inferred at the instrumented pad 16 and the magnitude is sufficient to cause alarm, relevant attributes and timing can be passed to the car's data control unit 23); ii) drawing inferences from the data received from at least two of the sensors (5) regarding the performance of the railcar (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment); and iii) communicating a message to a remote receiver when an anomaly is detected (col. 9, lines 12-13, regarding when serious trouble is inferred by the data control unit 23, then messages are sent via the communications link 23a, 24 to the locomotive).

Regarding claim 61, LeFebvre discloses the invention in claim 60, and LeFebvre further discloses wherein said sensors (5) comprise • accelerometers positioned at different locations of the railcar (col. 3, lines 27-28, regarding the pads 16 are seated on the upper rectangular surface of the bearing adapter 4; figs. 2 and 4), and wherein said step of drawing inferences (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) comprises the comparison of data from two or more of said accelerometers (col. 9, lines 49-54, regarding using load sensors mounted in the instrumented pad 16 on both wheel sets on a truck to detect longitudinal, lateral and yawing forces and monitor rapidly changing loads).

Regarding claim 62, LeFebvre discloses the invention in claim 60, and LeFebvre further discloses wherein said sensors (5) comprise temperature sensors positioned at different locations of the railcar (col. 3,

lines 27-28, regarding the pads 16 are seated on the upper rectangular surface of the bearing adapter 4; figs. 2 and 4), and wherein said step of drawing inferences (col. 6, lines 12-17, regarding the data control unit uses inference engine techniques to identify unsatisfactory behavior such as swaying, bouncing or even partial derailment) comprises the comparison of data from two or more said temperature sensors (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold).

Regarding claim 63, LeFebvre discloses the invention in claim 61, and LeFebvre further discloses wherein said accelerometers are positioned on the railcar (col. 3, lines 27-28, regarding the pads 16 are seated on the upper rectangular surface of the bearing adapter 4; figs. 2 and 4) to provide data for carrying out one or more of the following functions: i) compare accelerations from one railcar wheel with that of another railcar wheel on the same axle but opposite side of the railcar (col. 9, lines 49-54, regarding using load sensors mounted in the instrumented pad 16 on both wheel sets on a truck to detect longitudinal, lateral and yawing forces and monitor rapidly changing loads), ii) compare accelerations from one railcar wheel with that of at least one other wheel on the same side of said railcar (col. 10, lines 16-17, regarding monitoring the vertical loads in the instrumented pads and comparing these between wheel sets), and iii) compare accelerations from one railcar wheel with that of at least one other railcar wheel on the same side of said one railcar wheel and which other wheel is on another railcar (railroad freight car 22) of the same train consist (col. 7, lines 12-14, regarding it would be feasible to let the instrumented pads 16 communicate along the train, passing messages from one freight car to the next).

Regarding claim 64, LeFebvre discloses the invention in claim 61, and LeFebvre further discloses wherein said accelerometers are positioned on the railcar (col. 3, lines 27-28, regarding the pads 16 are seated

on the upper rectangular surface of the bearing adapter 4; figs. 2 and 4) to provide data for carrying out one or more of the following functions: i) compare accelerations from front and back ends of said railcar, ii) compare accelerations from any two locations on the railcar, and iii) compare accelerations from one railcar (col. 10, lines 16-17, regarding monitoring the vertical loads in the instrumented pads and comparing these between wheel sets) with those of another in the same train (col. 7, lines 12-14, regarding it would be feasible to let the instrumented pads 16 communicate along the train, passing messages from one freight car to the next).

Regarding claim 65, LeFebvre discloses the invention in claim 62, and LeFebvre further discloses wherein said temperature sensors are positioned on the railcar (col. 3, lines 27-28, regarding the pads 16 are seated on the upper rectangular surface of the bearing adapter 4; figs. 2 and 4) to provide data for comparing temperature data from one railcar wheel bearing (bearing adapter 4) with that of another railcar wheel bearing (bearing adapter 4) on the same axle but on an opposite side of the railcar (col. 9, lines 16-19, regarding a temperature sensor in instrumented pad 16 monitors relative changes in temperature against other bearings and provides an alarm threshold or long term trends to link to bearing condition; figs. 2 and 4).

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.

Claim 31, 32, 45, and 47 is/are rejected under 35 U.S.C. 103 as being unpatentable over LeFebvre et al. (7,668,218) in view of Brown et al. (2009/0173840). Regarding claim 31, LeFebvre discloses the invention in claim 1.

However, LeFebvre fails to specifically disclose the invention further comprising a powered wireless gateway controlling a train-based network that includes said powered wireless gateway and a plurality of said communication management units.

Brown is in the field of rail car sensor networks (abstract) and teaches the invention further comprising a powered wireless gateway (gateway member 120; fig. 3) controlling a train-based network (network 2; fig. 1) that includes said powered wireless gateway (gateway member 120) and a plurality of said communication management units (para. [0018], regarding gateway member 120 collects rail car parameter data passed through sensor assemblies 122-126; fig. 3).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine the teaching of Brown with the invention of LeFebvre in order to centralize control of the train-based network (see Brown, para. [0018]).

Regarding claim 32, LeFebvre as modified discloses the invention in claim 31.

However, LeFebvre fails to specifically disclose wherein said powered wireless gateway serves as said remote receiver.

Brown teaches wherein said powered wireless gateway (gateway member 120) serves as said remote receiver (para. [0018], regarding gateway member 120 collects rail car parameter data passed through sensor assemblies 122-126; fig. 3).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine the teaching of Brown with the invention of LeFebvre in order to centralize control of the train-based network (see Brown, para. [0018]).

Regarding claim 45, LeFebvre discloses the invention in claim 36.

However, LeFebvre fails to specifically disclose wherein all communication management units on said train consist are configured in a train-based wireless mesh network controlled by a powered wireless gateway.

Brown teaches wherein all communication management units (sensor assemblies 122-126; fig. 3) on said train consist (rail car system 93; fig. 3) are configured in a train-based wireless mesh network (network 2; fig. 1) controlled by a powered wireless gateway (para. [0018], regarding gateway member 120 collects rail car parameter data passed through sensor assemblies 122-126; fig. 3).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine the teaching of Brown with the invention of LeFebvre in order to centralize control of the train-based network (see Brown, para. [0018]).

Regarding claim 47, LeFebvre as modified discloses the invention in claim 45.

However, LeFebvre fails to specifically disclose wherein said remote receiver is said powered wireless gateway.

Brown teaches wherein said remote receiver is said powered wireless gateway (para. [0018], regarding gateway member 120 collects rail car parameter data passed through sensor assemblies 122-126; fig. 3).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine the teaching of Brown with the invention of LeFebvre in order to centralize control of the train-based network (see Brown, para. [0018]).

Allowable Subject Matter

Claims 51-53 and 55 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to JASON C SMITH whose telephone number is (571)270-5225. The examiner can normally be reached on Monday - Friday 8:30 AM - 5:00 PM.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Joseph Morano can be reached on (571) 272-6684. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Jason C Smith/
Primary Examiner, Art Unit 3617

Notice of References Cited	Application/Control No. 15/108,065	Applicant(s)/Patent Under Reexamination LeFebvre et al.	
	Examiner JASON C SMITH	Art Unit 3617	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20110282540-A1	11-2011	Armitage; David L.	H04Q9/00	701/31.4
*	B	US-20110270475-A1	11-2011	BRAND; John	B61L15/0027	701/20
*	C	US-20100200307-A1	08-2010	TOMS; ROBERT S.	G01G19/042	177/163
*	D	US-20090173840-A1	07-2009	Brown; Richard H.	B61L15/0027	246/1R
*	E	US-20090001226-A1	01-2009	Haygood; Hal B.	B61K9/00	246/169S
*	F	US-20080195265-A1	08-2008	Searle; Donald Stephen	B61K9/04	701/19
*	G	US-20070241610-A1	10-2007	Smith; Eugene A.	B60T13/66	303/22.6
*	H	US-7698962-B2	04-2010	LeFebvre; William	B61F5/305	177/136
*	I	US-7688218-B2	03-2010	LeFebvre; William	B61K9/00	246/169R
*	J	US-8370006-B2	02-2013	Kumar; Ajith Kuttannair	B61L3/006	701/19
*	K	US-7336156-B2	02-2008	Arita; Setsuo	H04B3/60	180/2.1
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	:	
	:	
William LeFebvre et al.	:	Confirmation No.: 1019
	:	
Application No.: 15/108,065	:	Group Art Unit: 3617
	:	
Filed: June 24, 2016	:	Examiner: Jason Smith

Title: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

AMENDMENT AND RESPONSE TO OFFICE ACTION AND REQUEST FOR EXAMINER INTERVIEW

This Amendment and Response to Office Action, along with a request for a two-month extension of time, and Request for Examiner Interview is in reply to the Office Action dated November 1, 2017 in this patent application.

Amendments to the Claims begin on page 2.

Remarks begin on page 16.

Request for Interview begins on page 20.

Electronic Patent Application Fee Transmittal

Application Number:	15108065
Filing Date:	24-Jun-2016
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Filer:	Gary A. Hecht/Natalie Ward
Attorney Docket Number:	P37056A US (37659.00060)

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	1615	6	100	600
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Extension - 2 months with $0 paid	1252	1	600	600
Miscellaneous:				
			Total in USD ($)	**1200**

Electronic Acknowledgement Receipt

EFS ID:	32194131
Application Number:	15108065
International Application Number:	
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht
Filer Authorized By:	
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	29-MAR-2018
Filing Date:	24-JUN-2016
Time Stamp:	14:55:12
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1200
RAM confirmation Number	033018INTEFSW14590300
Deposit Account	501943
Authorized User	Natalie Ward

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Response_to_OA_00060.pdf	57751 501499484230a9bd676c2e10414d86e3280de6b4	yes	20

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Letter Requesting Interview with Examiner	20	20
	Applicant Arguments/Remarks Made in an Amendment	16	19
	Claims	2	15
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	32998 2e2fcc7b219251cea49678a6048725e422b80a22	no	2

Warnings:

Information:

Total Files Size (in bytes):	90749

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

CONCLUSION AND REQUEST FOR INTERVIEW

For the reasons stated in this document, Applicant respectfully asks the Office to reconsider and withdraw all rejections in this case.

If the next Office Action will not result in allowance of the claims, Applicant respectfully requests an interview to discuss any remaining issues. Applicant invites the Examiner to contact the undersigned attorney to schedule a time that is convenient for the Examiner.

The Commissioner is hereby authorized to charge any additional fees which may be required for this Response, or credit any overpayment, to Deposit Account No. 50-1943.

Respectfully submitted,

FOX ROTHSCHILD LLP

/Brienne S. Terril/

Brienne S. Terril
Registration No. 60,941

/gah/

Gary A. Hecht
Registration No. 36,826

Fox Rothschild LLP
Princeton Pike Corporate Center
997 Lenox Drive, Building 3
Lawrenceville, NJ 08648-2311
Telephone: 412-391-2404
Facsimile: 609-896-1469
Date: March 29, 2018

REMARKS

In the Office Action, the Office rejected claims 1-65. More specifically:

- The Office rejected claims 1-30, 33-44, 46, 48-50, 54 and 60-65 under 35 U.S.C. §102(a)(1) as being anticipated by U.S. Patent No. 7,668,218 to LeFebvre et al. ("LeFebvre"); and

- The Office rejected claims 31, 32, 45 and 47 under 35 U.S.C. §103(a) as being unpatentable over LeFebvre in view of U.S. Patent Application No. 2009/0173840 to Brown et al. ("Brown").

Claims 1, 2, 4, 8, 9, 14-21, 27, 28, 31, 35, 36, 39, 42, 49,52, 56, 60, and 61 have been amended, and claims 66-71 have been added. Upon entry of these amendments and remarks, claims 1, 2, 4, 5, 8, 9, 11-21, 27, 28, 31, 35, 36, 39, 42, 45, 49, 52, 56, 60, 61, 66-71 will remain pending. For the reasons discussed below, Applicant asks the Office to withdraw all rejections in this case.

Note Regarding Examination

Applicant filed the present application on June 24, 2016 along with a Preliminary Amendment ("Preliminary Amendment") which amended and canceled certain claims. The Office, in the Office Action dated November 1, 2017, appears to have considered and examined the claims as filed rather than the claims as amended in the Preliminary Amendment of. For instance, on page 3 of the Office Action, the Office provides an explanation for the rejection of claim 3. However, Applicant canceled claim 3 in the Preliminary Amendment.

Because the Office examined the originally-filed claims, certain rejections in the Office Action do not align with the current claims. As such, Applicant respectfully requests that the Office update its analysis to reflect the limitations of the currently-pending claims.

Rejections Under 35 U.S.C. §102(a)(1)

Independent Claim 1

Amended independent claim 1 is patentable over LeFebvre because LeFebvre fails to teach or suggest each and every limitation of independent claim 1. Specifically, LeFebvre fails to teach or suggest at least the following:

- one or more sensors located on said one or more railcars configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

- one or more filters configured to filter at least a portion of the accelerations.

Claim 1 has been amended to require "one or more sensors configured to measure accelerations of the railcar" and "one or more filters configured to filter at least a portion of the accelerations."

LeFebvre is directed to a "monitoring system for railroad trains and the like, and more particularly a system that uses an instrumented roller bearer adapter pad to detect the occurrence and cause of poor performance at wheel set, truck, freight car or train level." LeFebvre at 1:5-10. However, LeFebvre fails to teach or suggest "one or more filters configured to filter at least a portion of" "accelerations of the railcar."

Accordingly, for at least these reasons, amended independent claim 1 is patentable over LeFebvre. In addition, because claims 2, 4, 5, 8, 9, 11-21, 27, 28, 31, 49, 52 and 66-71 depend from and incorporate all of the limitations of claim 1, these dependent claims are also patentable over LeFebvre and nonobvious over LeFebvre. Accordingly, Applicant respectfully asks the

Office to withdraw the §102(a)(1) rejections associated with claims 1, 2, 4, 5, 8, 9, 11-21, 27, 28, 31, 49, 52 and 66-71.

Independent Claim 35

Amended independent claim 35 is patentable over LeFebvre because LeFebvre fails to teach or suggest each and every limitation of independent claim 35. Specifically, LeFebvre fails to teach or suggest at least the following:

- sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars; and
- filtering, by one or more filters, at least a portion of the accelerations.

For reasons similar to those presented above with respect to claim 1, amended claim 35 is patentable over LeFebvre because LeFebvre fails to teach or suggest each and every limitation of amended claim 35. In addition, because claims 36, 39, 42, and 45 depend from and incorporate all of the limitations of claim 35, these dependent claims are also patentable over LeFebvre. Accordingly, Applicant respectfully asks the Office to withdraw the §102(a)(1) rejections associated with claims 35, 36, 39, 42 and 45.

Independent Claim 60

Amended independent claim 60 is patentable over LeFebvre because LeFebvre fails to teach or suggest each and every limitation of independent claim 60. Specifically, LeFebvre fails to teach or suggest at least the following:

- at least two sensors located on the said railcar configured to sense operational parameters of the railcar, said sensors being in communication with said communication

management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

- one or more filters configured to filter at least a portion of the accelerations.

For reasons similar to those presented above with respect to claim 1, amended claim 60 is patentable over LeFebvre because LeFebvre fails to teach or suggest each and every limitation of amended claim 60. In addition, because claim 61 depends from and incorporate all of the limitations of claim 60, this dependent claim is also patentable over LeFebvre. Accordingly, Applicant respectfully asks the Office to withdraw the §102(a)(1) rejections associated with claims 60 and 61.

Independent Claim 56

The Office Action does not address independent claim 56. It is not identified in the Office Action Summary, nor is it identified or addressed in the Detailed Correspondence. Applicant respectfully requests that the Office inform Applicant as to the status of independent claim 56.

Allowable Subject Matter

On page 23 of the Office Action, the Office indicated that claims 51-53 and 55 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Claims 51-53 and 55 were all directed to specific filter implementations. However, each of these claims was canceled without prejudice in the Preliminary Amendment.

Applicant notes that independent claims 1, 35 and 60 presented in this Amendment and Response each require one or more filters, and new claims 66-71 include the same and/or similar limitations to those presented in previous claims 51-53 and 55.

AMENDMENTS TO THE CLAIMS

1 (Currently Amended). A system for detecting operational anomalies on a train consist or railcar comprising:

(a) one or more communication management units mounted on one or more railcars; ~~and~~

(b) one or more sensors located on said one or more railcars ~~for sensing~~ configured to sense an operational parameter of said one or more railcars, said sensors being in communication with said one or more communication management units, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

(c) one or more filters configured to filter at least a portion of the accelerations,

wherein said communication management units perform the functions of:

(i) collecting data regarding said one or more railcar operational parameters;

(ii) analyzing said collected data for trends or events indicative of an anomalous operational condition; and

(iii) communicating a message to a remote receiver when said trend or event is detected.

2 (Currently Amended). The system of claim 1 further comprising one or more wireless sensor nodes in communication with one of said communication management units, said one or more sensors forming part of said one or more wireless sensor nodes;

wherein each of said wireless sensor nodes ~~performs the functions of~~ is configured to:

~~collecting~~ collect data from one or more sensors;

~~comparing~~ compare said data against one or more rules; and

~~sending~~ send a message to said communication management unit when at least one of said rules is satisfied; and

wherein said communication management unit and said wireless sensor nodes form a railcar-based wireless mesh network, said railcar-based mesh network being controlled by said communication management unit.

3 (Canceled).

4 (Currently Amended). The system of claim 2 wherein each of said wireless sensor nodes ~~performs the functions of~~ is configured to:

a) ~~collecting~~ collect data from one or more sensors; and

b) periodically ~~sending~~ send said collected data to said communication management unit.

5 (Previously Presented). The system of claim 2 wherein said one or more rules are numerical thresholds which, when exceeded by said collected data, cause an alert message to be sent to said communication management unit.

6 (Canceled).

7 (Canceled).

8 (Currently Amended). The system of claim 2 wherein said communication management unit, upon receiving an alert message from one of said wireless sensor nodes, ~~performs the functions of~~ is configured to:

(a) ~~waiting~~ wait to see if similar messages are received from one or more other wireless sensor nodes within a predetermined period of time and concluding that an actual event has occurred if said similar messages are received; and

(b) ~~communicating~~ communicate a message reporting the occurrence of said actual event to a remote receiver.

9 (Currently Amended). The system of claim 4 wherein said communication management unit, upon receiving said periodically sent data, ~~performs the functions of~~ is configured to:

(a) ~~storing~~ store said data in a data store;

(b) ~~analyzing~~ analyze said stored data for trends; and

(c) ~~generating~~ generate a report when trends of interest are detected.

10 (Previously Presented). The system of claim 1 further comprising a powered wireless gateway controlling a train-based wireless mesh network that includes said powered wireless gateway and a plurality of said communication management units,

11 (Previously Presented). The system of claim 1 wherein at least one of said communication management units includes at least one of said sensors.

12 (Previously Presented). The system of claim 10 wherein said powered wireless gateway serves as said remote receiver.

13 (Previously Presented). The system of claim 1 wherein said remote receiver is located off-train.

14 (Currently Amended). The system of claim 8 wherein said communication management unit is configured to confirm ~~confirms~~ that vertical hunting is occurring when vertical hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

15 (Currently Amended). The system of claim 14 wherein said communication management unit is configured to determine ~~determines~~ that a body bounce event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate in phase accelerations were detected.

16 (Currently Amended). The system of claim 14 wherein said communication management unit is configured to determine ~~determines~~ that a body pitch

event has occurred when messages from said wireless sensor nodes indicate that vertical hunting messages received from said wireless sensor nodes indicate out of phase accelerations were detected.

17 (Currently Amended). The system of claim 8 wherein said communication management unit is configured to confirm ~~confirms~~ that a lateral extreme vehicle dynamic event has occurred when lateral extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

18 (Currently Amended). The system of claim 8 wherein said communication management unit is configured to confirm ~~confirms~~ that a vertical extreme vehicle dynamic event has occurred when vertical extreme vehicle dynamic messages have been received from a plurality of wireless sensors nodes within said predetermined period of time.

19 (Currently Amended). The system of claim 8 wherein said communication management unit is configured to confirm ~~confirms~~ that lateral hunting is occurring when lateral hunting messages are received from wireless sensor nodes mounted on opposite ends of a railcar within a predetermined period of time.

20 (Currently Amended). The system of claim 19 wherein said communication management unit is configured to determine ~~determines~~ that a body yaw

event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate out of phase accelerations were detected.

21 (Currently Amended). The system of claim 19 wherein said communication management unit is configured to determine ~~determines~~ that a body roll event has occurred when messages from said wireless sensor nodes indicate that lateral hunting messages received form said wireless sensor nodes indicate in phase accelerations were detected.

22-26. (Canceled)

27 (Currently Amended). The system of claim *2* wherein said communication management unit ~~can~~ is configured to instruct each wireless sensor node to enable or disable the checking of individual rules by sending a message to said wireless sensor node.

28 (Currently Amended). The system of claim 4 wherein said communication management unit ~~can~~ is configured to instruct each wireless sensor node to enable or disable the periodic sending of data by sending a message to said wireless sensor node.

29-30 (Canceled).

31. (Currently Amended) The system of claim 1 further comprising a powered wireless gateway configured to control ~~controlling~~ a train-based network that includes said powered wireless gateway and a plurality of said communication management units.

32.-34 (Canceled).

35 (Currently Amended). A method for detecting operational anomalies on a train consist or railcar comprising the steps of:

sensing, by one or more sensors located on one or more railcars, one or more operational parameters of the one or more railcars, wherein the one or more operational parameters comprise one or more accelerations of the one or more railcars;

filtering, by one or more filters, at least a portion of the accelerations; and

by one or more communication management units associated with the one or more railcars:

~~(a)~~ collecting data regarding said one or more railcar operational parameters;

~~(b)~~ analyzing said collected data for trends or events indicative of an anomalous operational condition; and

~~(c)~~ communicating a message to a remote receiver when said trend or event is detected.

36 (Currently Amended). The method of claim 35 wherein ~~steps (a) – (c) are performed by a communication management unit located on a railcar in said train consist;~~

~~wherein~~ said data is collected from one or more wireless sensor nodes on said railcar, said wireless sensor nodes being in communication with said communication management unit and comprising one or more of the sensors; and

wherein said communication management unit and said one or more wireless sensor nodes form a railcar-based mesh network.

37 (Canceled).

38 (Canceled).

39 (Currently Amended). The method of claim 36 wherein said wireless sensor nodes are each ~~perform the functions of~~ configured to:

(a) ~~collecting~~ collect data from one or more sensors;

(b) ~~comparing~~ compare said data against one or more rules; and

(c) ~~sending~~ send a message to said communication management unit when at least one of said rules is satisfied; and

wherein said one or more rules causes data collected from some sensors to be periodically sent to said communication management unit.

40 (Canceled).

41 (Canceled).

42 (Currently Amended). The method of claim 39 wherein said communication management units are configured to coordinate ~~coordinates~~ messages from two or more wireless sensor nodes to confirm that an event has occurred.

43 (Canceled).

44 (Canceled).

45 (Previously Presented). The method of claim 36 wherein multiple railcars in said train consist are configured with a communication management unit and further wherein all communication management units on said train consist are configured in a train-based wireless mesh network controlled by a powered wireless gateway.

46-48 (Canceled).

49 (Currently Amended). The system of claim 2 wherein one of said wireless sensor nodes comprises:

a) a protective housing;

b) said one or more sensors being mounted within said protective housing ~~and includes a sensor to measure accelerations~~;

c) a communication capability, for communicating with said communication management unit;

d) a microprocessor, configured to execute ~~executing~~ firmware to control the operation of said wireless sensor node; and

e) a mechanical filter which includes a resilient material selected to filter out undesirable accelerations, said mechanical filter disposed to remove said undesirable accelerations before said undesirable accelerations reach said accelerometer.

50 (Canceled).

51 (Canceled).

52 (Currently Amended). The system of claim 2 wherein one of said wireless sensor nodes comprises:

a) a protective housing;

b) said one or more sensors being mounted within said protective housing ~~and includes a sensor to measure accelerations~~;

c) a communication capability, for communicating with said communication management unit;

d) a microprocessor, configured to execute ~~executing~~ firmware to control the operation of said wireless sensor node; and

e) potting material disposed within said housing, said potting material ~~used~~ configured to tune said wireless sensor node by absorbing undesirable accelerations.

53-55 (Canceled).

56 (Currently Amended). A system for detecting operational anomalies on a train consist or railcar comprising:

(a) a train-based mesh network comprising a powered wireless gateway and one or more communication management units located on one or more railcars in said train consist;

(b) one or more railcar-based mesh networks each comprising at least said one or more communication management units, each arranged in a mesh network configuration with one or more wireless sensor nodes;

(c) a distributed ~~complex~~ event processing engine ~~distributed across~~ that executes within the said wireless sensor nodes, said communication management units and said powered wireless gateway, said distributed ~~complex~~ event processing engine detecting anomalous operating conditions on said train consist via data gathered by sensors controlled by said wireless sensor nodes and propagated upwards through said system.

57-59 (Canceled).

60 (Currently Amended). A system for detecting operational anomalies on a railcar that is part of a train consist comprising:

(a) at least one communication management unit (CMU) mounted on the a railcar in said train consist;

(b) at least two sensors located on the said railcar ~~for sensing~~ configured to sense operational parameters of the railcar, said sensors being in communication with said communication management unit, wherein the one or more sensors comprise one or more sensors configured to measure accelerations of the railcar; and

(c) one or more filters configured to filter at least a portion of the accelerations,

wherein said communication management unit performs the following functions:

(i) receiving data from said sensors;

(ii) drawing inferences from the data received from at least two of the sensors regarding the performance of the railcar; and

(iii) communicating a message to a remote receiver when an anomaly is detected.

61 (Currently Amended). The system of claim 60,

wherein said sensors comprise accelerometers positioned at different locations of the railcar,

~~and~~ wherein said step of drawing inferences comprises the comparison of data from two or more of said accelerometers,

wherein said accelerometers are positioned on the railcar to provide data for carrying out one or more of the following functions:

i) compare accelerations from one railcar wheel with that of another railcar wheel on the same axle but opposite side of the railcar,

ii) compare accelerations from one railcar wheel with that of at least one other wheel on the same side of said railcar, and

iii) compare accelerations from one railcar wheel with that of at least one other railcar wheel on the same side of said one railcar wheel and which other wheel is on another railcar of the same train consist.

62-65 (Canceled).

66. (New) The system of claim 1, wherein the one or more filters comprise one or more mechanical filters that include a resilient material configured to filter out undesirable accelerations from the accelerations, wherein the one or more mechanical filters are disposed to remove the undesirable accelerations before the undesirable accelerations reach the one or more sensors that are configured to measure accelerations.

67. (New) The system of claim 1, further comprising one or more wireless sensor nodes in communication with at least one of the communication management units, wherein the one or more sensors form part of the one or more wireless sensor nodes, wherein one or more of the wireless sensor nodes comprise a protective housing, wherein the one or more sensors are mounted within the protective housing, wherein the protective housing comprises potting material configured to tune the wireless sensor nodes by absorbing at least a portion of undesirable accelerations.

68. (New) The system of claim 1, further comprising one or more wireless sensor nodes in communication with at least one of the communication management units, wherein the one or more sensors form part of the one or more wireless sensor

nodes, wherein one or more of the wireless sensor nodes comprises a microprocessor configured to execute firmware to control operation of the one or more of the wireless sensor nodes, wherein the firmware comprises one or more software filters configured to isolate one or more types of accelerations.

69. (New) The system of claim 1, wherein the one or more filters comprise one or more mechanical filters.

70. (New) The system of claim 1, wherein the one or more filters comprise one or more electronic filters.

71. (New) The system of claim 1, wherein the one or more filters comprise one or more digital filters.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 15/108,065	Filing Date 06/24/2016	☐ To be Mailed

ENTITY: ☑ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $80 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $420 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	03/29/2018	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 37	Minus	** 31	= 6		x $100 =	600
	Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	= 0		x $460 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	600

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	REGINALD TYSON
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

29880 7590 05/10/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NEW JERSEY 08648
UNITED STATES OF AMERICA

EXAMINER	
SMITH, JASON C	
ART UNIT	**PAPER NUMBER**
3617	

DATE MAILED: 05/10/2018

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

TITLE OF INVENTION: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	08/10/2018

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

29880 7590 05/10/2018
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NEW JERSEY 08648
UNITED STATES OF AMERICA

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

TITLE OF INVENTION: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	08/10/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
SMITH, JASON C	3617	246-16900R

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

29880 7590 05/10/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NEW JERSEY 08648
UNITED STATES OF AMERICA

EXAMINER	
SMITH, JASON C	
ART UNIT	PAPER NUMBER
3617	

DATE MAILED: 05/10/2018

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/108,065	Applicant(s) LeFebvre et al.	
	Examiner JASON C SMITH	Art Unit 3617	AIA Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 03/29/2018.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/JASON C SMITH/
Primary Examiner, Art Unit 3617

Continuation of 3. The allowed claim(s) is/are: 1-2,4-5,8-9,11-21,27-28,31,35-36,39,42,45,49,51-52,60 and 66-71

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	Art Unit
	JASON C SMITH	3617

CPC - Searched*		
Symbol	Date	Examiner
B60T 17/22	10/27/2017	jcs
B61L 15/00, 0018, 0027, 0054, 0072, 0081	10/27/2017	jcs
G01K 7/02	10/27/2017	kcs
G06F 19/00	10/27/2017	jcs
G08B 21/18	10/27/2017	jcs

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
east text search	10/27/2017	jcs
searches updated	04/27/2018	jcs

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
B61L	15/00, 0018, 0027, 0054, 0072, 0081	04/27/2018	jcs

/Jason C Smith/ Primary Examiner, Art Unit 3617	

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

CPC						
Symbol					**Type**	**Version**
B61L	/	27	/	0094	F	2013-01-01
B61L	/	15	/	0027	I	2013-01-01
B61L	/	15	/	0081	I	2013-01-01
B61K	/	9	/	00	I	2013-01-01
B61K	/	9	/	04	I	2013-01-01
B61L	/	25	/	021	I	2013-01-01
B61L	/	25	/	025	I	2013-01-01
B61L	/	27	/	0077	I	2013-01-01
G01M	/	17	/	10	I	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	37	
/JASON C SMITH/ Primary Examiner, Art Unit 3617	27 April 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20180427

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

INTERNATIONAL CLASSIFICATION					
CLAIMED					
B61L	/	27	/	00	
NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	37	
/JASON C SMITH/ Primary Examiner, Art Unit 3617	27 April 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	19	10	16	19	7	28		37		46		55		64
2	2	21	11	17	20		29		38		47	35	56		65
	3	20	12	18	21		30	32	39		48		57	23	66
6	4	29	13		22	22	31		40	3	49		58	24	67
9	5	13	14		23		32		41		50		59	25	68
	6	14	15		24		33	33	42		51	36	60	26	69
	7	15	16		25		34		43	4	52	37	61	27	70
10	8	11	17		26	30	35		44		53		62	28	71
8	9	12	18	5	27	31	36	34	45		54		63		

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	37	
/JASON C SMITH/ Primary Examiner, Art Unit 3617	27 April 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20180427

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	1	"15108065"	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:13
S2	28	("20050259619" | "20060264221" | "20070241610" | "20080195265" | "20090001226" | "20090173840" | "20100200307" | "20110270475" | "20110282540" | "3718040" | "5446451" | "5603556" | "5682139" | "5691980" | "6175784" | "6184798" | "6301531" | "6339397" | "6668216" | "7336156" | "7688218" | "7698962" | "8244411" | "8370006" | "8672273" | "8751290" | "9365223" | "9663092").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:14
S3	1769	b60t17/22.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S4	36	b61l15/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S5	584	g01k7/02.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S6	1843	g06f19/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S7	2244	g08b21/18	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S8	116	246/129.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S9	3732	340/438.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S10	1338	340/870.16.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S11	737	340/870.17.ccls.	US-PGPUB;	OR	OFF	2017/10/27 16:19

			USPAT; USOCR			
S12	470	374/152.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S13	1525	701/19.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S14	543	701/20.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S15	725	b61l15/0027.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S16	127	b61l15/0054.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S17	342	b61l15/0072.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S18	435	b61l15/0081.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S19	59	b61l15/0018.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S20	388	martin adj andrew.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S21	42	cooper adj francis.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S22	1	adamec adj rachel.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S23	243	b61l27/0094.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S24	83	b61k9/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S25	295	b61k9/04.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21

S26	608	b61l25/021.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S27	869	b61l25/025.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21

4/27/2018 8:34:22 AM
C:\Users\jsmith8\Documents\EAST\Workspaces\15108065.wsp

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

CPC						
Symbol					**Type**	**Version**
B61L	/	27	/	0094	F	2013-01-01
B61L	/	15	/	0027	I	2013-01-01
B61L	/	15	/	0081	I	2013-01-01
B61K	/	9	/	00	I	2013-01-01
B61K	/	9	/	04	I	2013-01-01
B61L	/	25	/	021	I	2013-01-01
B61L	/	25	/	025	I	2013-01-01
B61L	/	27	/	0077	I	2013-01-01
G01M	/	17	/	10	I	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 35	
/JASON C SMITH/ Primary Examiner, Art Unit 3617 (Primary Examiner) (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office Part of Paper No.: 20180521

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

INTERNATIONAL CLASSIFICATION					
CLAIMED					
B61L	/	27	/	00	
NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 35	
/JASON C SMITH/ Primary Examiner, Art Unit 3617 (Primary Examiner) (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	18	10	13	19	5	28		37		46		55		64
2	2	20	11	14	20		29		38		47	33	56		65
	3	19	12	15	21		30		39		48		57	23	66
3	4	21	13		22	22	31		40	17	49		58	24	67
6	5	8	14		23		32		41		50		59	25	68
	6	9	15		24		33	32	42		51	34	60	26	69
	7	10	16		25		34		43		52	35	61	27	70
7	8	11	17		26	29	35		44		53		62	28	71
4	9	12	18	16	27	30	36	31	45		54		63		

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 35	
/JASON C SMITH/ Primary Examiner, Art Unit 3617 (Primary Examiner)	(Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office Part of Paper No.: 20180521

PTO/SB/30EFS (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL
(Submitted Only via EFS-Web)

Application Number	15108065	Filing Date	2016-06-24	Docket Number (if applicable)	P37056A US (037659.00060)	Art Unit	3617
First Named Inventor	William LeFebvre			Examiner Name	Jason C. Smith		

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

SUBMISSION REQUIRED UNDER 37 CFR 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

- ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ☐ Other _____

☒ Enclosed

- ☐ Amendment/Reply
- ☒ Information Disclosure Statement (IDS)
- ☐ Affidavit(s)/ Declaration(s)
- ☐ Other _____

MISCELLANEOUS

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months _____ (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☐ Other _____

FEES

☒ **The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**
The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to Deposit Account No 501943

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

☒ Patent Practitioner Signature

Applicant Signature

PTO/SB/30EFS (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Signature of Registered U.S. Patent Practitioner			
Signature	/gah/	Date (YYYY-MM-DD)	2018-08-08
Name	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:	15108065
Filing Date:	24-Jun-2016
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Filer:	Gary A. Hecht
Attorney Docket Number:	P37056A US (37659.00060)

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
RCE- 1ST REQUEST	1801	1	1300	1300
		Total in USD ($)		**1300**

Electronic Acknowledgement Receipt

EFS ID:	33412447
Application Number:	15108065
International Application Number:	
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht
Filer Authorized By:	
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	08-AUG-2018
Filing Date:	24-JUN-2016
Time Stamp:	16:54:47
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1300
RAM confirmation Number	080918INTEFSW16571100
Deposit Account	501943
Authorized User	Natalie Ward

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Foreign Reference	JP2009210301A_NSK_LTD_00060.pdf	721760 d5b4bf5abe8d6a2257c3c4b165af6af2074de025	no	17
Warnings:					
Information:					
2	Foreign Reference	JP2004294419A_Denso_Corp_00060.pdf	547466 065223ac0c89f784738d39f848c03b89542c0660	no	14
Warnings:					
Information:					
3	Non Patent Literature	Japanese_Office_Action.pdf	108941 97300f25a552a6fc07cbba323021ae3ca57ac685	no	3
Warnings:					
Information:					
4	Translation of Foreign Priority Documents	Translation_of_OA.pdf	79897 02ceadf79440bab2dcce688699c050476bd00301	no	4
Warnings:					
Information:					
5	Translation of Foreign Priority Documents	Machine_translation_00060.pdf	1049924 b828a30790024cd58c7ad533609097f405866e36	no	21
Warnings:					
Information:					
6	Information Disclosure Statement (IDS) Form (SB08)	60119564_1.pdf	1131236 b8dfb67bba6bf2c05e20d329a85e2add2070377d	no	4
Warnings:					
Information:					

7	Request for Continued Examination (RCE)	RCE_Transmittal_Form.pdf	1376640 4d3874c3466d085c442b8c99430dcbabfc29232e	no	3
Warnings:					
Information:					
8	Fee Worksheet (SB06)	fee-info.pdf	30786 ceee86bdacc1e0438173922 4dd0776bafee1a7f1	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	5046650		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2009-210301
(P2009-210301A)
(43)公開日　平成21年9月17日(2009.9.17)

(51)Int.Cl.		F I		テーマコード（参考）
G01M 13/02	(2006.01)	G01M	13/02	2G024
F16C 19/52	(2006.01)	F16C	19/52	2G064
F16C 33/32	(2006.01)	F16C	33/32	3J104
F16C 33/34	(2006.01)	F16C	33/34	3J701
F16C 33/62	(2006.01)	F16C	33/62	

審査請求 未請求　請求項の数 8　ＯＬ　（全 17 頁）　最終頁に続く

(21)出願番号　特願2008-51246 (P2008-51246)
(22)出願日　平成20年2月29日 (2008.2.29)

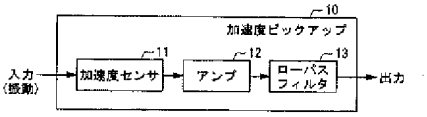
(71)出願人　000004204
日本精工株式会社
東京都品川区大崎１丁目６番３号
(74)代理人　100066980
弁理士　森　哲也
(74)代理人　100075579
弁理士　内藤　嘉昭
(74)代理人　100103850
弁理士　崔　秀▲てつ▼
(72)発明者　殿谷　雅人
神奈川県藤沢市鵠沼神明一丁目５番５０号
日本精工株式会社内

Ｆターム(参考)　2G024 AB11　BA27　CA13　DA09
2G064 AA17　AB01　AB02　BA02　BD18

最終頁に続く

(54)【発明の名称】転動装置及び転動装置の異常検出方法

(57)【要約】
【課題】転動装置の異常を高い精度で検出する。
【解決手段】転動装置は、第１の軌道部材及び第２の軌道部材の何れかに取り付けられ、振動時の加速度に応じた電圧を出力する加速度センサ１１と、加速度センサ１１の出力電圧値を増幅するアンプ１２と、アンプ１２の出力電圧について、設定した周波数成分を減衰させるローパスフィルタ１３とを備える。ローパスフィルタ１３は、第１の軌道部材と第２の軌道部材との相対運動に伴い転動体循環路を転動体が移動するときに幾何学的に算出される特定周波数に対して、８倍、好ましくは６倍を超える周波数を減衰させる。
【選択図】図１



【特許請求の範囲】
【請求項1】
第１の軌道部材、第２の軌道部材及び複数の転動体からなり、前記第１の軌道部材と第２の軌道部材それぞれに設けられた軌道溝、及び一方の軌道部材内に設けられた戻し路により構成される少なくとも１つの転動体循環路内に転動自在に前記転動体を介挿することで、前記第１の軌道部材と第２の軌道部材とを相対移動させる転動装置において、
前記第１の軌道部材及び第２の軌道部材の何れかに取り付けられ、振動時の加速度に応じた電圧を出力する加速度センサと、前記加速度センサの出力電圧を増幅する増幅手段と、前記加速度センサの出力電圧、又は増幅手段の出力電圧について、設定した周波数成分を減衰させるフィルタ手段とを備え、
前記フィルタ手段は、前記第１の軌道部材と第２の軌道部材との相対運動に伴い前記転動体循環路を前記転動体が移動するときに幾何学的に算出される特定周波数に対して、８倍を超える周波数を減衰させることを特徴とする転動装置。
【請求項2】
前記フィルタ手段は、２０ｄＢ／ｄｅｃ以上の減衰特性を持つことを特徴とする請求項１に記載の転動装置。
【請求項3】
前記フィルタ手段は、前記特定周波数に対して、４倍、６倍及び８倍の周波数のうちの少なくとも何れかを６ｄＢ／ｏｃｔ以上の減衰特性で減衰させることを特徴とする請求項１に記載の転動装置。
【請求項4】
前記加速度センサの周波数特性が１０ＫＨｚ以上に渡り略線形であり、前記増幅手段は、前記加速度センサからの出力電圧を基に、非線形出力を行うことを特徴とする請求項１～３の何れか１項に記載の転動装置。
【請求項5】
前記フィルタ手段は、弾性体で構成される機械的フィルタであることを特徴とする請求項１～４の何れか１項に記載の転動装置。
【請求項6】
前記第１の軌道部材の軌道溝及び第２の軌道部材の軌道溝の何れかがゴシックアーチ形状であることを特徴とする請求項１～５の何れか１項に記載の転動装置。
【請求項7】
前記第１及び第２の軌道部材、並びに前記転動体は、金属又はセラミックで形成されることを特徴とする請求項１～６の何れか１項に記載の転動装置。
【請求項8】
請求項１～７の何れか１項に記載の転動装置の前記第１の軌道部材及び第２の軌道部材の何れかが直動したときの振動を検出し、その検出値から前記転動装置の異常を検出する転動装置の異常検出方法において、
特定周波数の振動を監視して、前記転動装置の異常を検出することを特徴とする転動装置の異常検出方法。

【発明の詳細な説明】
【技術分野】
【0001】
本発明は、軌道部材間に設けた転動路に複数の転動体を配置し、軌道部材同士を相対移動させる転動装置、及びそのような転動装置の異常を検出する異常検出方法に関する。
【背景技術】
【0002】
例えば、転がり軸受の軌道面に何らかの原因で欠陥が生じた場合には、その部分を転動体が通過するたびに衝撃が伴い、振動が発生する。このように発生する装置や転がり要素からの振動を測定し、その測定した振動の変化を基に異常を判定する方法が、従来より種々提案されている。しかし、いずれも、一般的な測定周波数範囲内で異常を判定している

ので、高い精度で異常を検出することはできない。
【0003】
例えば、特許文献１では、転がり軸受の異常を検出すために、測定周波数範囲の下限側を９ｋＨｚ～１０ｋＨｚとし、加速度検出器の特性等を基に、測定周波数範囲の上限側を２５ｋＨｚ～３０ｋＨｚとしている。そして、測定した振動加速度を周波数解析し、その解析結果から得た周波数スペクトルのピーク値を基に、異常を検出している。また、そのような周波数解析を必要としない方法として、特許文献２では、一般的な機械設備の測定周波数範囲を２０ｋＨｚ～５０ｋＨｚとしている。そして、振動波形の絶対値の累積度数分布を求め、等価実効値、振動波形の最大値、及びそのピーク比の大きさを基に、異常を診断している。
【0004】
ここで、振動を検出するセンサとして振動センサがある。特許文献３には、そのような振動センサが開示されている。特許文献３では、ボールねじにおける振動を振動センサで検出する技術が開示されている。そのような振動センサとしては、小型で扱いやすく、検出周波数帯やダイナミックレンジが広い圧電式加速度センサ（加速度ピックアップ）が広く普及している。この振動センサは、振動（加速度、速度、変位）を電気信号に変換するものであり、大別して、チャージ出力型加速度ピックアップと、アンプ内蔵型圧電式加速度ピックアップとがある。チャージ出力型加速度ピックアップは、検出した振動を電荷として出力する電荷出力型のピックアップであり、出力された電荷を電圧にチャージアンプにより変換する。また、アンプ内蔵型圧電式加速度ピックアップは、検出した振動を電圧として出力する。
【特許文献1】特開昭６１－２８８１２６号公報
【特許文献2】特開２００１－３０４９５４号公報
【特許文献3】特開２００１－３４９４０７号公報
【発明の開示】
【発明が解決しようとする課題】
【0005】
ところで、前記特許文献１や特許文献２のように、一般的な測定周波数範囲をもって、異常を検出しようとすると、異常（異常を示す振動）が生じても、それが正常時の振動や他のノイズに隠れてしまい、発生している異常を見逃すという問題があった。
特に、ボールねじや直動案内軸受装置等のような転動装置の場合では、転動体がほぼ一定間隔で並び常にほぼ一定の拘束状態にある回転転がり軸受のような転動装置とは異なること等、特有な問題があるため、そのような傾向が顕著であった。
【0006】
本発明の課題は、転動装置の異常を高い精度で検出することである。
【課題を解決するための手段】
【0007】
前記課題を解決するために、本発明に係る請求項１に記載の転動装置は、第１の軌道部材、第２の軌道部材及び複数の転動体からなり、前記第１の軌道部材と第２の軌道部材それぞれに設けられた軌道溝、及び一方の軌道部材内に設けられた戻し路により構成される少なくとも１つの転動体循環路内に転動自在に前記転動体を介挿することで、前記第１の軌道部材と第２の軌道部材とを相対移動させる転動装置において、前記第１の軌道部材及び第２の軌道部材の何れかに取り付けられ、振動時の加速度に応じた電圧を出力する加速度センサと、前記加速度センサの出力電圧を増幅する増幅手段と、前記加速度センサの出力電圧、又は増幅手段の出力電圧について、設定した周波数成分を減衰させるフィルタ手段とを備え、前記フィルタ手段は、前記第１の軌道部材と第２の軌道部材との相対運動に伴い前記転動体循環路を前記転動体が移動するときに幾何学的に算出される特定周波数に対して、８倍を超える周波数を減衰させることを特徴とする。
【0008】
また、本発明に係る請求項２に記載の転動装置は、請求項１に記載の転動装置において

、前記フィルタ手段が、２０ｄＢ／ｄｅｃ以上の減衰特性を持つことを特徴とする。
　また、本発明に係る請求項３に記載の転動装置は、請求項１に記載の転動装置において、前記フィルタ手段が、前記転動体の計算通過周波数、並びに該転動体の計算通過周波数に対して、４倍、６倍及び８倍の周波数のうちの少なくとも何れかを６ｄＢ／ｏｃｔ以上の減衰特性で減衰させることを特徴とする。
【0009】
　また、本発明に係る請求項４に記載の転動装置は、請求項１～３の何れか１項に記載の転動装置において、前記加速度センサの周波数特性が１０ＫＨｚ以上に渡り略線形であり、前記増幅手段が、前記加速度センサからの出力電圧を基に、非線形出力を行うことを特徴とする。
　また、本発明に係る請求項５に記載の転動装置は、請求項１～４の何れか１項に記載の転動装置において、前記フィルタ手段が、弾性体で構成される機械的フィルタであることを特徴とする。
【0010】
　また、本発明に係る請求項６に記載の転動装置は、請求項１～５の何れか１項に記載の転動装置において、前記第１の軌道部材の軌道溝及び第２の軌道部材の軌道溝の何れかがゴシックアーチ形状であることを特徴とする。
　また、本発明に係る請求項７に記載の転動装置は、請求項１～６の何れか１項に記載の転動装置において、前記第１及び第２の軌道部材、並びに前記転動体が、金属又はセラミックで形成されることを特徴とする。
【0011】
　また、本発明に係る請求項８に記載の転動装置の異常検出方法は、請求項１～７の何れか１項に記載の転動装置の前記第１の軌道部材及び第２の軌道部材の何れかが直動したときの振動を検出し、その検出値から前記転動装置の異常を検出する転動装置の異常検出方法において、特定周波数の振動を監視して、前記転動装置の異常を検出することを特徴とする。
【発明の効果】
【0012】
　請求項１及び８に係る発明によれば、転動装置において、特定周波数に対して、８倍を超える周波数を減衰させることで、監視対象の振動を正確に検出し、監視対象の異常を正確に検出できる。
　また、請求項３に係る発明によれば、個別の事象を加味してフィルタリングができるので、監視対象の振動をより正確に検出できる。
　また、請求項５に係る発明によれば、フィルタ手段を簡単に構成できる。
【0013】
　また、軌道溝がゴシックアーチ形状に形成されている場合、研削砥石を左右に振る超仕上げができないので、転動体が軌道溝を転走するときにその凹凸により振動が発生するのは必至である。請求項６に係る発明によれば、このような場合に発生する振動検出の監視対象外となる周波数の振動に応じた出力電圧を低下させる、すなわち検出感度を下げることができる。
　また、軌道部材や転動体が金属又はセラミックで形成される場合、転動体が軌道溝を転走するときにその凹凸により振動が発生するのは必至である。請求項７に係る発明によれば、このような場合に発生する振動検出の監視対象外の周波数の振動に応じた出力電圧を低下させる、すなわち検出感度を下げることができる。
【発明を実施するための最良の形態】
【0014】
　本発明を実施するための最良の形態（以下、実施形態という。）を図面を参照しながら詳細に説明する。
（第１の実施形態）
　先ず第１の実施形態を説明する。

（構成）
第１の実施形態は振動センサを構成する加速度ピックアップであり、図１は、その加速度ピックアップ１０の構成を示す。図１に示すように、加速度ピックアップ１０は、アンプ内蔵型圧電式加速度ピックアップである。すなわち、加速度ピックアップ１０は、振動時の加速度に応じた電圧を出力する圧電式の加速度センサ１１と、加速度センサの出力電圧値を増幅するアンプ１２と、電気的フィルタであるローパスフィルタ１３とを備える。ここで、加速度センサ１１は、長さ方向に伸縮する圧電素子２枚を接合し、一方が伸びると他方が縮むように構成した撓み振動子、いわゆるバイモルフ型の圧電加速度センサである。加速度センサ１１の特性は、例えば最大出力電圧範囲又は振動周波数が１ＫＨｚ時の加速度１Ｇでの出力電圧範囲が定められている。例えば、出力電圧範囲は±５Ｖである。

【0015】
ローパスフィルタ１３は、加速度ピックアップ１０が取り付けられる被測定物又は監視対象（転動装置の軌道部材又は転がり要素部材）の固有振動数以上の振動周波数帯（振動周波数成分）をフィルタリング（沪波）するように設定されている。具体的には、ローパスフィルタ１３は、加速度ピックアップ１０が取り付けられる被測定物で得られる特定の周波数に対してｎ倍にある周波数帯をフィルタリングする。ここで、特定の周波数とは、例えば、以下の（１）式～（３）式により算出される転動体の計算通過周波数である。また、ｎ倍とは、８倍好ましくは６倍である。なお、この（１）式～（３）式は、転動装置がボールねじに対応した式である。

$$z \cdot f_c = z \cdot (1 - (D_w \cdot \cos\alpha \cdot \cos^2\beta / d_m)) \cdot f_r / 2 \ [Hz] \quad \cdots (1)$$

$$z \cdot f_i = z \cdot (1 + (D_w \cdot \cos\alpha \cdot \cos^2\beta / d_m)) \cdot f_r / 2 \ [Hz] \quad \cdots (2)$$

$$2 \cdot f_b = 2 \cdot (d_m / (D_w \cdot \cos^2\alpha \cdot \cos^2\beta) - (D_w \cdot \cos^2\alpha \cdot \cos^2\beta / d_m)) \cdot f_r / 2 \ [Hz] \quad \cdots (3)$$

【0016】
ここで、ｚは１リード当たりの負荷玉数である（$z = \pi \cdot d_m / (D_w \cdot \cos\beta)$）。また、$f_c$は、玉の公転周波数［Ｈｚ］である。すなわち、$f_c$は１個の転動体が１リード分を公転する周波数であり、ナットに対する転動体の運動を示す。また、f_iは、玉の公転周波数に対するねじ軸の相対回転周波数［Ｈｚ］である。すなわち、f_iは、玉の公転周波数f_cを基準にねじ軸が１リード分公転する周波数であり、転動体に対する軸の運動を示す。また、f_bは、玉の自転周波数［Ｈｚ］であり、f_rは軸回転周波数［Ｈｚ］である。また、D_wは玉径［ｍｍ］であり、d_mは玉ピッチ径［ｍｍ］であり、αは接触角［°］であり、βはリード角［°］である。

【0017】
前記（１）式、（２）式及び（３）式によって算出される周波数は、ボールねじに発生する損傷発生部位と高い相関がある。このようなことから、各式で算出される周波数のスペクトルピークの増大によって、どの部位に損傷が発生したかわかる。具体的には、（１）式では、玉によりナットが受ける損傷（損傷時の周波数）がわかり、（２）式では、玉により軸が受ける損傷（損傷時の周波数）がわかり、前記（３）式では、玉の損傷（損傷時の周波数）がわかる。このような（１）式～（３）式で求められるもののうち最も大きなものを特定の周波数としている。

【0018】
ローパスフィルタ１３は、前記（１）式～（３）式に基づいて算出した転動体の計算通過周波数に対し、８倍、好ましくは６倍の周波数帯をフィルタリングして出力する。このローパスフィルタ１３は、２０ｄＢ／ｄｅｃ以上の減衰特性を有している。図２は、その減衰特性を示す。また、図３は、そのような減衰特性を実現するローパスフィルタ１３の構成の一例を示す。

【0019】

図４～図７は、加速度ピックアップ１０（振動センサ）の取り付け例を示す。図４に示すように、加速度ピックアップ１０は、ボールねじ３０におけるナット３２のフランジ部３２ａの外周面に取り付けられる。また、図５に示すように、加速度ピックアップ１０は、ナット３２のフランジ部３２ａの移動方向に向く側面に取り付けられる。また、図６に示すように、加速度ピックアップ１０は、案内レール９１とスライダ９２とからなるリニアガイド（直動案内装置）９０の該スライダ９２の移動方向に対して平行な側面に取り付けられる。また、図７に示すように、加速度ピックアップ１０は、スライダ９２の移動方向に向く側面に取り付けられる。

【0020】

（動作、作用及び効果）

動作、作用及び効果は次のようになる。

前記図４～図７の例に示すように、軌道部材（ナット３２やスライダ９２）に加速度ピックアップ１０を取り付ける。これにより、加速度ピックアップ１０では、軌道部材の移動で該軌道部材に生じた振動（加速度）に応じて加速度センサ１１が信号を出力する。そして、アンプ１２が、その加速度センサ１１の出力信号を増幅して、ローパスフィルタ１３に出力する。ローパスフィルタ１３は、アンプ１２からの信号をフィルタリングして、外部出力する。

【0021】

ここで、このようなボールねじやリニアガイドでは、循環する転動体が非負荷圏から負荷圏に進入する際に軌道面と衝突し、その衝突による軌道面側の軌道部材の自由振動が励起されて、軌道部材の固有振動数を周波数とする振動が発生する。このような軌道部材に加速度ピックアップ１０を取り付けると、加速度ピックアップ１０は、転動体と軌道面との衝突により励振される自由振動に起因する軌道部材の固有振動数を高い感度で検出してしまう。このようなことから、本実施形態では、ローパスフィルタ１３は、加速度ピックアップ１０を取り付ける軌道部材の固有振動数以上の振動周波数帯をフィルタリングしている。すなわち、ローパスフィルタ１３は、転動体の計算通過周波数に対して８倍、好ましくは６倍の周波数帯をフィルタリングしている。ここで、被測定物がボールねじの場合には、前記（１）式～（３）式を基に転動体の計算通過周波数を算出している。

【0022】

ここで、次のような理由から転動体の計算通過周波数に対して８倍、好ましくは６倍の周波数帯をローパスフィルタ１３でフィルタリングしている。

図８は、ボールねじの振動加速度の周波数解析の結果を示す。この結果は、ボールねじにおいて転動体が剥離するといった異常が発生したときのものであり、その異常発生前後の振動周波数解析結果を示す。同図中、太線は異常発生前の結果であり、細線は異常発生後の結果である。同図に示すように、異常発生前及び異常発生後ともに、５ｋＨｚ付近の周波数帯において、転勤体と軌道面との衝突により、加速度ピックアップが取り付けてある軌道部材であるナットの自由振動が励起されて、該軌道部材の固有振動数を周波数とする振動が発生しているのがわかる。しかし、６ｋＨｚ以上の周波数帯では、異常発生前後による明確な差異が認められなくなる。その一方で、３ｋＨｚ以下の周波数帯では、回転速度に対して幾何学的比例関係にある周波数成分の振動が明確に現れる。このようなことから、異常発生前後における加速度ピックアップによって検出する振動加速度信号について、５ｋＨｚ、好ましくは６ｋＨｚ以上の周波数帯をフィルタリングすれば、振動加速度信号のピーク値又はｒｍｓ値に明確な差異が現れることとなる。

【0023】

このとき、このような振動特性を有するボールねじについて、前記（１）式～（３）式により得られる前記転動体の計算通過周波数は５００Ｈｚ～７５０Ｈｚである。このようなことから、この転動体の計算通過周波数５００Ｈｚ～７５０Ｈｚの８倍以上となる５ｋＨｚ、好ましくは６ｋＨｚ以上の周波数帯をローパスフィルタ１３でフィルタリングすることで、振動加速度信号のピーク値又はｒｍｓ値に明確な差異を得ることができるようになる。または、（１）～（３）式で求められる周波数のうち最も大きなものを基準（特定

の周波数）とし、その８倍以上となるようにローパスフィルタを設定しても良い。
【0024】
また、次のような個別の事象を加味して、ローパスフィルタ１３によりフィルタリングする周波数帯を決定することもできる。
図９は、異常発生前後の振動加速度信号（加速度ピックアップの出力信号）のピーク－ピーク値変化率を示す。同図では、縦軸に、ピーク－ピーク値変化率として、異常発生後のピークと異常発生前のピークの比（異常発生後のピーク／異常発生前のピーク）をとっている。フィルタをかけない場合（同図中の●印）には、ピーク－ピーク値変化率について、異常発生前後で明確な差異を得ることはできない。すなわち、異常を検出することができない。また、６ｋＨｚのローパスフィルタをかけて、異常発生前後で明確な差異が生じない範囲である６ｋＨｚ以上の周波数帯をフィルタリングして得た振動加速度信号のピーク－ピーク値変化率（同図中の■印）についても、異常発生前後で明確な差異が現れにくくなっている。これは、５ｋＨｚ付近に発生する固有振動の周波数成分を除去できていないためである。これに対して、３ｋＨｚのローパスフィルタをかけた場合、固有振動の周波数成分等からなる５ｋＨｚ以上の固有振動周波数帯を充分にフィルタリングでき、差異が明確に現れるようになる。
【0025】
一般的には、転動体と軌道面との衝突によって励振される軌道部材の固有振動数が４ｋＨｚ～１００ｋＨｚの範囲にあること（下記図１０参照）、さらに、回転速度に対して幾何学的比例関係にある周波数成分の振動の影響が顕著に現れる周波数範囲が約３ｋＨｚまでである。このようなことから、ローパスフィルタ１３の設定値を３ｋＨｚにして、固有振動の周波数成分をフィルタリングすることで、幾何学的な振動の影響が顕著に現れる周波数範囲の振動を測定することの両方の目的を達成できる。なお、軌道部材の固有振動の周波数成分を予め確認できる場合にはその固有振動数以上の振動周波数帯を充分にフィルタリングできるように、ローパスフィルタを設定することもできる。
【0026】
また、極小の周波数帯（図８中、丸で囲う周波数帯）についても、ローパスフィルタ１３でフィルタリングするようにしても良い。すなわち、転動体の計算通過周波数に満たない周波数を減衰させる。例えば、転動体の計算通過周波数に満たない周波数として、ボールねじのねじ軸の共振周波数や転動装置外部からの振動によるもの、等がある。これにより、これらの振動を遮断することができ、振動加速度信号のピーク値又はｒｍｓ値をより明確な差異として得ることができるようになる。
【0027】
なお、以上のように複数の周波数帯をフィルタリングするため、減衰周波数の異なるフィルタ、特定の周波数のみを減衰させるノッチフィルタを用いると有効である。
図１０は、ボールねじに関し、周波数と振動強さ（ｄｂ）との関係を示す。同図（ａ）はφ５０のボールねじの結果であり、同図（ｂ）はφ３２のボールねじの結果である。前述のように、ボールねじでは、循環する転動体が非負荷圏から負荷圏に進入する際に軌道面と衝突し、その衝突による軌道面側の要素部材の自由振動が励起されて、要素部材の固有振動数を周波数とする振動が発生する。このような転動体と軌道面との衝突による固有振動の周波数帯は、ボールねじのナットの大きさで多少異なるものの、同図に丸で囲んで示すように、一般的には、４ｋＨｚ～１００ｋＨｚを超えるものとなる。
【0028】
また、転動体と軌道面との衝突により発生する振動の振幅は、その衝突エネルギーにより変化するため、例えば、個々の転動体の軌道面への進入角度の違いによって容易に変化する、又は往復する直動要素等においては往行時（図１１（ａ））と復行時（図１１（ｂ））の違い等によって容易に変化する。このため、循環部を持つ転がり要素においては、従来の方法では、異常を誤検出する可能性も高い。しかし、本発明を適用することで、このような条件下でも、特定の周波数、例えば、転動体の計算通過周波数の８倍以上となる周波数帯をフィルタリングすることで、異常を高い精度で検出できるようになる。

【0029】
図１２は、加速度ピックアップ１０の出力信号の利用例である。ここでは、加速度ピックアップ１０の出力信号を基に、転動装置（具体的には軌道部材、本例ではボールねじ３０やリニアガイド９０）１２０の異常を検出する異常検出システム１３０の構成を示す。
図１２に示すように、異常検出システム１３０は、転動装置１２０（例えばナット３２やスライダ９２）に取り付けられた加速度ピックアップ１０の出力信号を記憶する記憶部１３１と、記憶部１３１に記憶された出力信号を基に、振動加速度を外部出力（表示）する振動加速度表示部１３２と、記憶部１３１に記憶された出力信号を基に、異常判定を行う異常判定部１３３を備える。異常判定部１３３は、記憶部１３１に記憶された信号、すなわち、加速度ピックアップ１０の出力信号（振動加速度信号）の時系列信号を基に、該出力信号におけるピーク値又は該出力信号のｒｍｓ値を得て、それらピーク値又はｒｍｓ値を基に、転動装置１２０の異常を判定する。例えば、所定のしきい値と対比して、転動装置１２０の異常を判定する。
【0030】
これにより、加速度ピックアップ１０の出力信号（振動加速度振動）を用いて、高い精度で異常の判定をすることができる。また、出力信号の時系列変化を基に軌道部材の異常を判定するため、異常を高い精度で検出できる。また、周波数解析装置や複数の演算装置を用いることなく、フィルタ及びピーク値表示装置（振動加速度表示装置）だけで異常を検出することが可能となるため、簡単な構成でありながら、異常を高い精度で検出できる。
【0031】
なお、この第１の実施形態を次のような構成により実現することもできる。
すなわち、この第１の実施形態では、前記（１）式～（３）式は、ボールねじの転動体の計算通過周波数を得るためのものである。しかし、他の転動装置、例えばリニアガイドについて転動体の計算通過周波数を得る場合には、そのリニアガイドの寸法諸元や運転速度等の諸条件に応じて前記（１）式～（３）式を変形する。これにより、リニアガイドについて転動体の計算通過周波数を算出し、その転動体の計算通過周波数の８倍好ましくは６倍の周波数帯をフィルタリングすることで、リニアガイドの軌道部材（案内レールやスライダ）で発生する振動を高い精度で検出でき、異常を高い精度で検出できる。
【0032】
また、ローパスフィルタ１３は、転動体の計算通過周波数、並びに該転動体の計算通過周波数に対して、４倍、６倍及び８倍の周波数のうちの少なくとも何れかを６ｄＢ／ｏｃｔ以上の減衰特性で減衰させることもできる。これにより、減衰させたい周波数と異常検出の対象としたい周波数との適宜選別して、高い精度で異常検出できるようになる。例えば、転動体の計算通過周波数に対して４倍の周波数が目的以外の外乱周波数と一致する場合、これも減衰させ、転動体の計算通過周波数と６倍の周波数で異常検出を行うことにより、検出精度を向上させることができる。
また、この第１の実施形態では、加速度センサ１１の出力電圧をアンプ１２を介してローパスフィルタ１３に出力している。これに対して、加速度センサ１１の出力電圧をローパスフィルタ１３に直接出力し、フィルタリングしても、前述と同様な効果として、異常を高い精度で検出できる。
【0033】
（第２の実施形態）
次に第２の実施形態を説明する。
（構成）
第２の実施形態も本発明を適用した振動センサである。
図１３は、振動センサ２０の構成を示す。図１３に示すように、振動センサ２０は、加速度ピックアップ２１と被測定物（転動装置の軌道部材）２００との間に機械的なフィルタ手段をなす弾性体２５を配置して、この弾性体２５を介して被測定物２００に対して加速度ピックアップ２１を固定している。加速度ピックアップ２１は、アンプ内蔵型圧電式

加速度ピックアップである。この加速度ピックアップ２１は、弾性体２５を介して被測定物２００とねじ止めにより固定されている。

【0034】

図１４は、加速度ピックアップ２１の構成を示す。図１４に示すように、加速度ピックアップ２１は、振動時の加速度に応じた電圧を出力する圧電式の加速度センサ２２と、加速度センサの出力電圧値を増幅するアンプ２３とを備える。例えば、加速度センサ２２は、前記第１の実施形態と同様に、いわゆるバイモルフ型の圧電加速度センサである。

図１５は、加速度ピックアップ２１（具体的には加速度センサ２２）の特性を示す。図１５に示すように、加速度ピックアップ２１（具体的には加速度センサ２２）の周波数特性が１０ＫＨｚ以上に渡り略線形となる。アンプ２３は、このような特性を有する加速度センサ２２からの出力電圧値を基に、非線形出力を行う。

【0035】

弾性体２５は、ゴム又はエラストマ材等により形成されている。図１３に示すように、弾性体２５の中心にねじ挿通用の孔２５ａを設けて、この孔２５ａにねじ２６を挿通して、加速度ピックアップ２１と被測定物２００とをねじ止めしている。そして、対象測定周波数範囲外の振動を遮断できるように、弾性体２５の形状又は物性値等を決定している。すなわち、特定の周波数、例えば、転動装置について得られる転動体の計算通過周波数（転動装置がボールねじの場合は前記（１）～（３）式参照）に対して８倍、好ましくは６倍の周波数帯を機械的にフィルタリングできるように、弾性体２５の形状又は物性値等を決定している。

【0036】

図１６～図１８を用いて、振動センサ２０を備えた転動装置であるボールねじの構成例を説明する。図１６～図１８に示すように、ボールねじ３０は、一の軌道部材であるねじ軸３１と、このねじ軸３１の回転に伴って軸方向に相対移動する他の軌道部材であるナット３２と、このナット３２とねじ軸３１との間に転動自在に組み込まれた多数のボール３３と、これらのボール３３を循環させるボール循環部材としてのサイドキャップ３４とを備える。ねじ軸３１は軸方向と直交する断面が円形に形成されており、その外周面には軌道溝である螺旋状のボールねじ溝４１が形成されている。ボールねじ溝４１はナット３２の内周面に形成された軌道溝である螺旋状のボールねじ溝４２と対向しており、ねじ軸３１又はナット３２の一方が軸回りに回転すると、これに同期してボール３３がボールねじ溝４１，４２間に形成された転動路となるボール負荷転動路４３を転動するようになっている。

【0037】

ナット３２は、外周面にサイドキャップ取付け面５１を有しており、このサイドキャップ取付け面５１には、ボール３３を循環させるためのボール循環孔５２，５２が形成されている。サイドキャップ３４は、例えば、樹脂或いは金属等の成形材料を所定の形状に射出成形して形成されている。サイドキャップ３４はボール循環孔５２，５２に嵌合する一対の柱状ボールすくい上げ部３４ａ，３４ｂと、これらの柱状ボールすくい上げ部３４ａ，３４ｂ内に形成されたボール戻し案内路５３，５３と連通するボール戻し路５４を内部に有するプレート状のサイドキャップ本体部３４ｃとから構成されている。ここで、ボール負荷転動路４３、ボール戻し案内路５３及びボール戻し路５４を含む構造として、ボール３３を循環させる転動体循環路が構成されている。

【0038】

ボールすくい上げ部３４ａ，３４ｂは、その横断面が円形に形成されており、従って、ボールすくい上げ部３４ａ，３４ｂが嵌め込まれるボール循環孔５２の横断面も円形となっている。ボールすくい上げ部３４ａ，３４ｂは、不図示のタング部をそれぞれ有しており、ボール負荷転動路４３を転動するボール３３は、図１８に示すように、ボールすくい上げ部３４ａ又は３４ｂのタング部によりボールねじ溝４１，４２のリード角方向にすくい上げられてボール戻し路５４に導入されるようになっている。

【0039】

以上のように構成されるボールねじ３０のナット３２側の部材となるサイドキャップ３４に、図５に示すように振動センサ２０を装着している。このとき、加速度ピックアップ２１とナット３２との間に弾性体２５が介在するように振動センサ２０を装着している。振動センサ２０は、検出信号（電圧値）をセンサケーブル２７により外部出力している。

【0040】

（動作、作用及び効果）

動作、作用及び効果は次のようになる。

ナット３２とねじ軸３１とが相対移動したときの、ボールねじ３０における振動を振動センサ２０（具体的には加速度ピックアップ２１）により検出する。そして、振動センサ２０は、検出信号をセンサケーブル２７により外部出力している。このとき、加速度ピックアップ２１と被測定物２００との間に弾性体２５が存在するため、被測定物２００の振動信号が弾性体２５を介して加速度ピックアップ２１に伝達するようになる。これにより、弾性体２５がフィルタとして作用して、加速度ピックアップ２１に入力される前段階で、対象測定周波数範囲外の振動信号が遮断されるようになる。よって、加速度ピックアップ２１では、広い周波数範囲で高いレベルで振動を測定できる。また、フィルタ手段を弾性体２５とすることで、フィルタ手段を簡単に構成できる。

【0041】

ここで、ボールねじ、リニアガイド及びラックピニオン等の往復運動を繰り返す直動要素の振動検出にチャージ出力型加速度ピックアップを用いると、ケーブルの屈曲に伴うノイズが振動検出信号に乗ってしまうという問題があった。これに対して、アンプ内蔵型圧電式加速度ピックアップは、ケーブルの屈曲に伴うノイズが振動検出信号に乗ってしまうことはほとんどない。しかし、アンプ内蔵型圧電式加速度ピックアップは、チャージ出力型加速度ピックアップと比べて、ダイナミックレンジが狭く、オーバーロードし易いという問題があった。すなわち、アンプ内蔵型ピックアップでは、フィルタリングせずに振動が直接入力されるため、その振動が大きい場合には、内蔵するアンプがオーバーロードしてしまう（低周波数の振動より高周波数の振動の感度が大きくなる）。これにより、アンプ内蔵型ピックアップの用途は、内蔵するアンプがオーバーロードしない振動レベルの範囲内での振動測定に限られるものとなっていた。よって、ボールねじ、リニアガイド又はラックピニオン等の直動要素の振動では、研削痕をボールが走る振動等で高周波成分が強くなっているため、そのような振動の検出においては、アンプ内蔵型圧電式加速度ピックアップがオーバーロードし易くなるという問題が発生する。

【0042】

なお、外部アンプを使用するチャージ出力型加速度ピックアップでは、外部フィルタをかけて対象測定周波数範囲（監視対象の周波数範囲）を絞ることができるため、広周波数範囲にわたり高いレベルにある振動信号でも入力することができ、対象測定周波数範囲の振動を特定し、測定できる。しかし、チャージ出力型加速度ピックアップでは、前述のように、ボールねじ、リニアガイド及びラックピニオン等の往復運動を繰り返す直動要素の振動検出において、ケーブルの屈曲に伴うノイズが信号に乗ってしまうという問題を解消できない。

【0043】

以上のような種々の問題に対して、対象測定周波数範囲外の高周波成分からなる振動を加速度ピックアップ２１に入力される前段階で遮断することで、対象測定周波数範囲外の高周波成分に埋もれていた監視対象の振動（高周波成分の振動も含む）を検出できるようになる。また、対象測定周波数範囲外の高周波成分からなる振動を加速度ピックアップ２１に入力される前段階で遮断することで、加速度ピックアップ２１のオーバーロードの発生を防止して、監視対象の振動を確実に検出できるようになる。そして、加速度ピックアップ２１がアンプ内蔵型圧電式加速度ピックアップであることで、ケーブル屈曲によるノイズの影響を小さくできる。

【0044】

また、以下のような個別の事象を加味して、フィルタリングする周波数範囲を決定する

こともできる。
例えば、直動転がり要素の最高速度は、ボールねじの場合、ＤＮ＝160000ｍｍ／ｍｉｎに達しており、このときの転動体と軌道溝との相対速度は、約１．５ｍ／ｓである。また、軌道面は、超仕上げが実施されていないことにより、研削砥粒による研削痕を有しており、それによる転動体転走方向の凹凸のピッチは、加工条件にもよるが、およそ１５０μｍ以下、主には５０μｍ程度である。これより、転動体が最高速度で軌道溝を転走するとき、該軌道溝にある凹凸による振動周波数は、小さく見積もっても、１０ＫＨｚ（＝１．５・Ｅ６／１５０）であり、主には、３０ＫＨｚ（＝１．５・Ｅ６／５０）になる。このような周波数の振動に対する感度を下げて、加速度ピックアップ２１でモニタできれば、軌道面の剥離や玉詰まりに伴い発生する、より低周波の振動を検出できる。

【0045】

このようなことから、ボールと転動路（軌道溝）との衝突による３０ｋＨｚ以上の高周波数成分の振動が、対象測定周波数範囲外の振動となるように、弾性体２５の形状、物性値等を決定する。このようにすることで、ボールと転動路（軌道溝）との衝突による振動に対する感度を下げて、軌道面の剥離や玉詰まりに伴い発生する、より低周波の振動を加速度ピックアップ２１で検出できる。

【0046】

なお、直動転がり要素において軌道面の超仕上げを実施していない理由は例えば次のようになる。直動転がり要素（以下、軸受）では、一般的に軌道面の超仕上げを実施しているが、軌道溝は、軸受と異なり、有端の直線、又は螺旋状であることより、その長さ別の多品種少量生産とならざるを得ず、コスト的に難しいこと、及び、軌道溝が有端であることよりその使用速度が自ずと制限されるので、超仕上げに見合う性能を発揮し得ないこと、さらに、転動体が循環路と軌道溝を出入する際の振動により、超仕上げによる効果がマスキングされること、が挙げられる。

【0047】

また、特に、ねじ軸やナットのボールねじ溝がゴシックアーチ形状に形成されている場合、研削砥石を左右に振る超仕上げができないので、転動体がボールねじ溝を転走するときにその凹凸により振動が発生するのは必至である。このようなことから、その周波数の振動に対する感度を下げて、加速度ピックアップ２１でモニタすることにより、ボールねじ溝の軌道面の剥離や玉詰まりに伴い発生する、より低周波の振動を検出できる。

【0048】

また、特に、ねじ軸やナット（具体的にはそれらのボールねじ溝）、又は転動体が研削加工仕上げによる金属（例え鋼）やセラミックで形成されている場合にも、転動体がボールねじ溝を転走するときにその凹凸により振動が発生するのは必至である。このようなことから、その周波数の振動に対する感度を下げて、加速度ピックアップ２１でモニタすることにより、ボールねじ溝の軌道面の剥離や玉詰まりに伴い発生する、より低周波の振動を検出できる。

【0049】

また、超仕上げを行った場合、レベルは低下するものの、直動転がり要素では概ね同程度の高周波成分の振動を検出できる。この振動は、転動体が循環路と軌道溝とを出入する際に発生する高周波成分の振動と考えられる。このような場合でも、本発明を適用することで、そのような周波数の振動に対する感度を下げて、加速度ピックアップ２１でモニタすることにより、軌道面の剥離や玉詰まりに伴い発生する、より低周波の振動を検出できる。

【0050】

なお、この第２の実施形態を次のような構成により実現することもできる。
すなわち、この第２の実施形態では、ねじにより加速度ピックアップ２１及び弾性体２５を被測定物２００に固定している。これに対して、ワックス、接着剤、両面テープ又はマグネット等の他の固定手段で固定することもできる。例えば、加速度ピックアップ２１と弾性体２５、弾性体２５と被測定物２００との一方又は両方をワックス、接着剤、両面

テープ又はマグネット等で固定する。

【0051】

（第３の実施形態）

次に第３の実施形態を説明する。

第３の実施形態も振動センサであり、図１９は、その振動センサ６０の構成を示す。図１９に示すように、第３の実施形態における振動センサ６０は、加速度ピックアップ２１に質量部材６１を備えている。質量部材６１は、振動センサ６０（特に加速度ピックアップ２１）が所定の固有振動数になるように決定されている。このように、振動センサ６０（特に加速度ピックアップ２１）の固有振動数を質量部材６１により調整することで、該振動センサ６０で遮断対象となる高周波振動成分の範囲を調整できる。

【0052】

ここで、下記（４）式は、１次のバネマス系の固有振動数f_0を示す。

$$f_0 = 1/(2\pi)\cdot\sqrt{(k/M)} \quad \cdots (4)$$

ｋはバネ定数であり、Ｍは質量である。この（４）式を振動センサ６０の構成に適用すると、ｋは弾性体２５のばね定数であり、Ｍは質量部材６１を含めた加速度ピックアップ２１の質量である。よって、この（４）式からもわかるように、加速度ピックアップ２１に質量部材６１を付加することで、質量部材６１を含めた加速度ピックアップ２１の固有振動数f_0を変化させることができ、この結果、該振動センサ６０で遮断対象となる高周波振動成分の範囲（転動体の計算通過周波数に対して８倍、好ましくは６倍の周波数帯）を調整できるようになる。

【0053】

なお、この第３の実施形態では、加速度ピックアップ２１に質量部材６１を付加して、固有振動数を変化させているが、他の方法により固有振動数を変化させることもできる。すなわち、加速度ピックアップ２１と弾性体２５との固定方法、又は加速度ピックアップ２１と被測定物２００との固定方法を適宜変化させることでも、固有振動数を変化させることができる。また、弾性体２５の厚さや材料（物性値）等、加速度ピックアップ２１自体の重量を適宜変化させることでも、固有振動数を変化させることができる。

【0054】

（第４の実施形態）

次に第４の実施形態を説明する。第４の実施形態も振動センサであり、図２０は、その振動センサ７０の構成を示す。図２０に示すように、第４の実施形態における振動センサ７０は、加速度ピックアップ２１と弾性体２５、弾性体２５と被測定物２００それぞれをねじ７１，７２により個別に固定している。例えば、このような構成にすることで、振動センサ７０の固有振動数を変化させることができ、該振動センサ７０で遮断対象となる高周波振動成分の範囲を調整できる。

【0055】

（第５の実施形態）

次に第５の実施形態を説明する。第５の実施形態も振動センサであり、図２１は、その振動センサ８０の構成を示す。図２１に示すように、振動センサ８０は、加速度ピックアップ２１と弾性体２５、弾性体２５と被測定物２００それぞれを個別に固定している。第５の実施形態では、前記第４の実施形態の場合と異なり、弾性体２５の外周部を囲うような取り付け部材８２を用いて、該弾性体２５を被測定物２００に固定している。例えば、このような構成にすることで、振動センサ８０の固有振動数を変化させることができ、該振動センサ８０で遮断対象となる高周波振動成分の範囲を調整できる。

【図面の簡単な説明】

【0056】

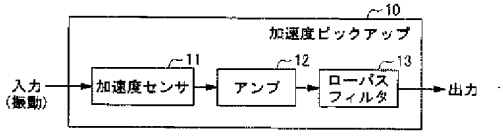
【図1】本発明の第１の実施形態の転動装置が備える振動センサ（加速度ピックアップ）の構成を示すブロック図である。

【図2】加速度ピックアップのローパスフィルタの減衰特性を示す特性図である。

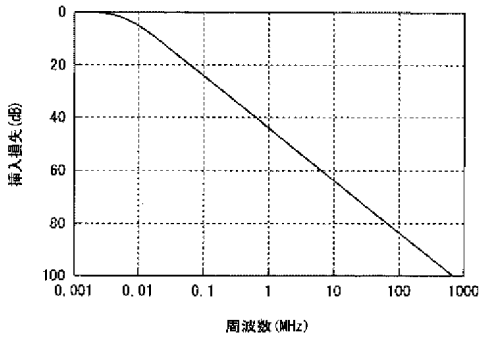
【図3】ローパスフィルタの構成の一例を示す回路図である。

【図4】ボールねじへの加速度ピックアップの取り付け例を示す図である。
【図5】ボールねじへの加速度ピックアップの他の取り付け例を示す図である。
【図6】リニアガイドへの加速度ピックアップの取り付け例を示す図である。
【図7】リニアガイドへの加速度ピックアップの他の取り付け例を示す図である。
【図8】ボールねじの振動加速度の周波数解析の結果を示す特性図である。
【図9】異常発生前後の振動加速度信号（加速度ピックアップの出力信号）のピーク－ピーク値変化率を示す特性図である。
【図10】ボールねじに関し、周波数と振動強さ（ｄｂ）との関係を示す特性図である。
【図11】直動要素等における往復時の振動の違いの説明に使用した特性図である。
【図12】速度ピックアップを備えた異常検出システムの構成を示すブロック図である。
【図13】本発明の第２の実施形態の転動装置が備える振動センサの構成を示す図である。
【図14】第２の実施形態における振動センサ（加速度ピックアップ）の構成を示すブロック図である。
【図15】第２の実施形態における加速度ピックアップの特性を示す特性図である。
【図16】振動センサを備えたボールねじの構成を示す平面図である。
【図17】振動センサを備えたボールねじの構成を示す軸方向断面図である。
【図18】振動センサを備えたボールねじの構成を示す径方向断面図である。
【図19】第３の実施形態の転動装置が備える振動センサの構成を示す図である。
【図20】第４の実施形態の転動装置が備える振動センサの構成を示す図である。
【図21】第５の実施形態の転動装置が備える振動センサの構成を示す図である。
【符号の説明】
【0057】
１０　加速度ピックアップ（振動センサ）、１１　加速度センサ、１２　アンプ、１３　ローパスフィルタ、２０　振動センサ、２１　加速度ピックアップ、２５　弾性体

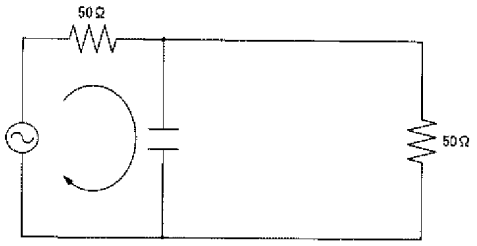
【図1】



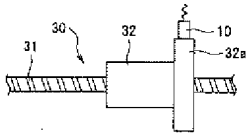
【図2】



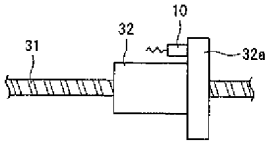
【図3】



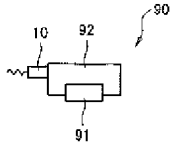
【図4】



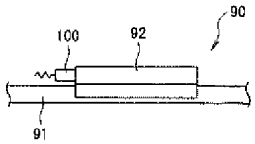
【図5】



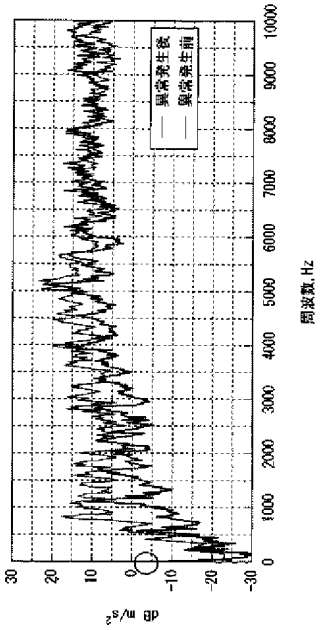
【図6】



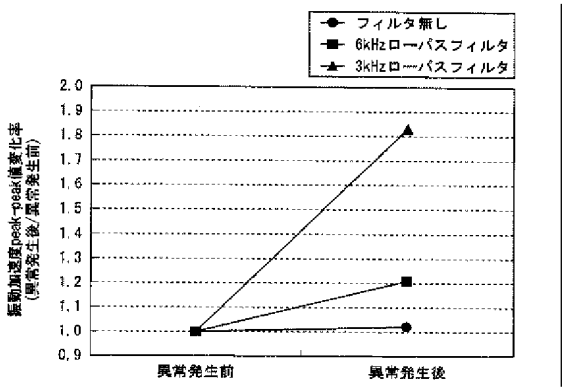
【図7】



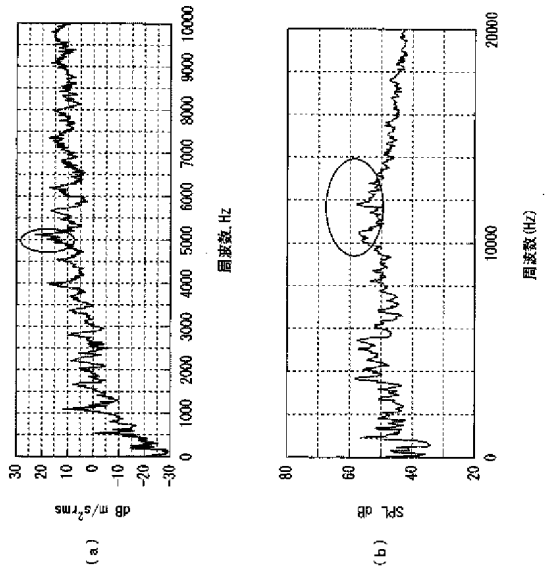
【図8】


異常発生後
異常発生前
周波数.Hz
dB m/s²

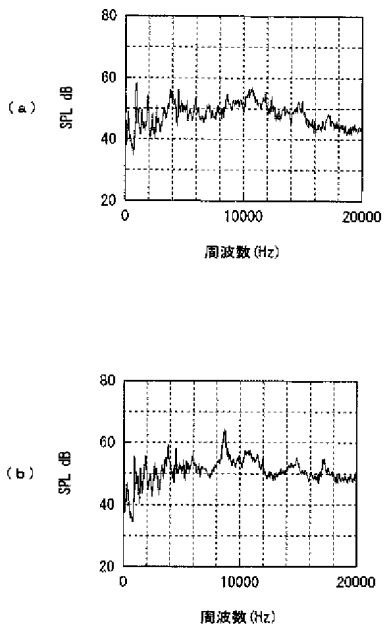
【図9】


フィルタ無し
6kHzローパスフィルタ
3kHzローパスフィルタ
振動加速度peak-peak値変化率
(異常発生後/異常発生前)
異常発生前
異常発生後

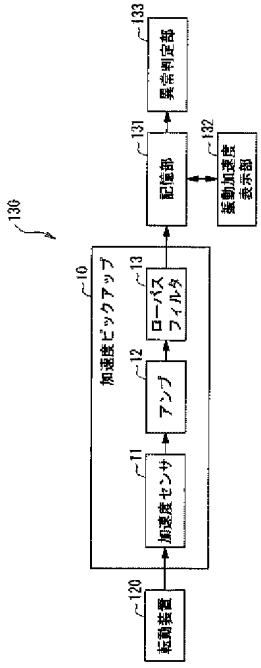
【図10】


周波数.Hz
dB m/s²rms
(a)
SPL dB
周波数(Hz)
(b)

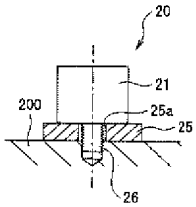
【図11】


(a)
SPL dB
周波数(Hz)
(b)
SPL dB
周波数(Hz)

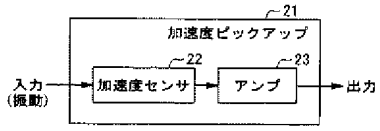
【図12】



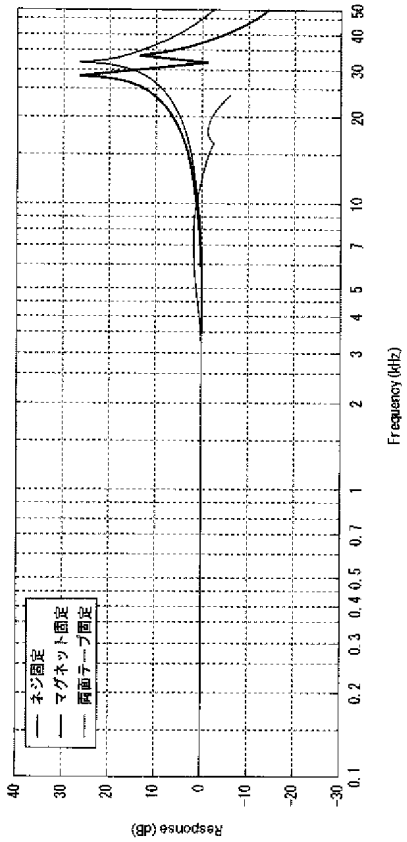
【図13】



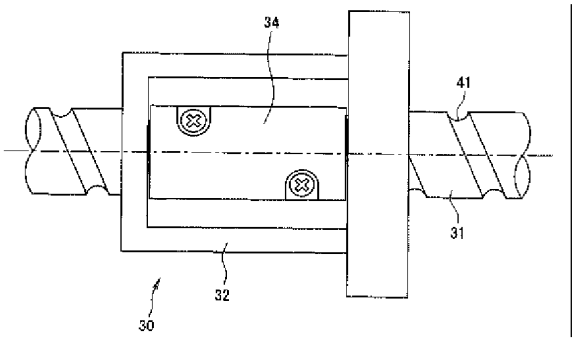
【図14】



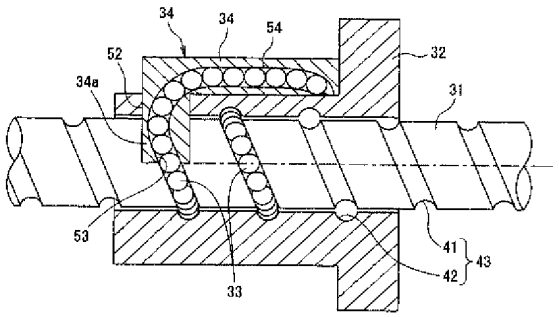
【図15】



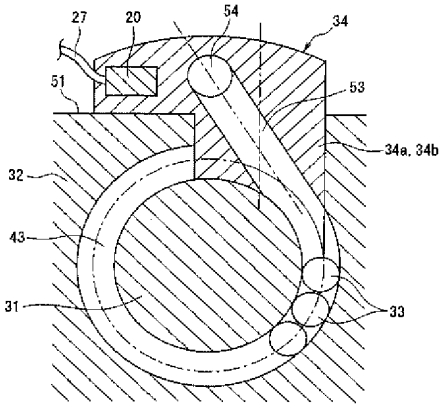
【図16】



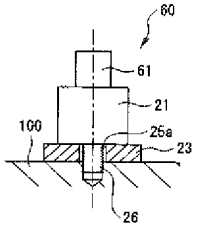
【図17】



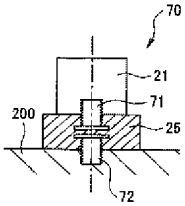
【図18】



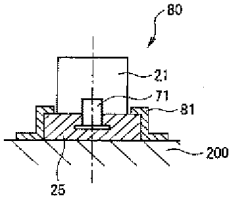
【図19】



【図20】



【図21】



(51)Int.Cl.			F I			テーマコード（参考）
Ｆ１６Ｃ	29/06	(2006.01)	Ｆ１６Ｃ	29/06		
Ｇ０１Ｈ	17/00	(2006.01)	Ｇ０１Ｈ	17/00	Ａ	

Ｆターム(参考) 3J104 AA02 AA23 BA80 CA02 CA11 DA20
3J701 AA02 AA64 BA80 EA02 EA41 FA23 FA26

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2004-294419
(P2004-294419A)
(43)公開日　平成16年10月21日(2004.10.21)

(51)Int.Cl.[7]	F I	テーマコード（参考）
G01P 15/08	G01P 15/08 P	

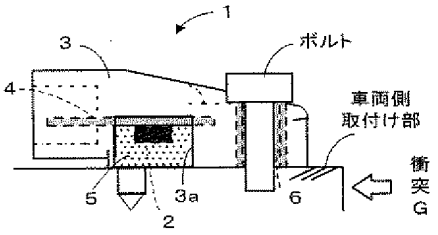
審査請求 未請求　請求項の数 8　OL　（全 13 頁）

(21)出願番号　特願2003-128265(P2003-128265)
(22)出願日　平成15年5月6日(2003.5.6)
(31)優先権主張番号　特願2003-25866(P2003-25866)
(32)優先日　平成15年2月3日(2003.2.3)
(33)優先権主張国　日本国(JP)

(71)出願人　000004260
株式会社デンソー
愛知県刈谷市昭和町１丁目１番地
(74)代理人　100081776
弁理士　大川　宏
(72)発明者　大西　純
愛知県刈谷市昭和町１丁目１番地　株式会社デンソー内

(54)【発明の名称】センサ装置

(57)【要約】
【課題】共振の原因となる高周波振動を確実に減衰させ、衝突・振動等を正確に検出することが可能なセンサ装置を提供する。
【解決手段】センシング部の物理的変位に応じて電気信号が出力されるGセンサ２と、そのGセンサ２が搭載される筐体３とを備えたセンサ装置１において、筐体収容部３ａ内にポッティング剤５が封止され、Gセンサ２がポッティング剤によって覆われているので、共振の原因となる高周波振動が確実に減衰し、Gセンサ２は、共振の影響を受けることなく、衝突、振動の正しい検出出力を行うことができる。
【選択図】　図１



【特許請求の範囲】
【請求項1】
センシング部の物理的変位に応じて電気信号が出力される電子式センサと、その電子式センサが搭載される筐体とを備えたセンサ装置において、
前記電子式センサの少なくとも一部と前記筐体との間に高周波振動を減衰させる振動減衰部材を設けたことを特徴とするセンサ装置。
【請求項2】
前記振動減衰部材は、ポッティング剤からなり、
前記電子式センサは、前記ポッティング剤によって覆われたことを特徴とする請求項１に記載のセンサ装置。
【請求項3】
前記振動減衰部材は、板状若しくはシート状の防振材又は前記電子式センサに成形加工された防振材からなり、
前記電子式センサは、前記防振材を介して前記筐体に固定されたことを特徴とする請求項１に記載のセンサ装置。
【請求項4】
前記振動減衰部材は、前記電子式センサに少なくとも一部が接続され且つ前記筐体に少なくとも他の一部が固定されたバネ性を有するリード部材からなり、
そのリード部材と前記電子式センサの質量とからなるバネ－マス系によって高周波振動を減衰させるように構成されたことを特徴とする請求項１又は２に記載のセンサ装置。
【請求項5】
前記リード部材は、前記筐体に一体成形されていることを特徴とする請求項４に記載のセンサ装置。
【請求項6】
前記電子式センサは、検知部、通信部、電源回路等が１パッケージ化されて、前記筐体に直付けされたことを特徴とする請求項１乃至５のいずれかに記載のセンサ装置。
【請求項7】
前記電子式センサは基板上に実装され、その基板を介して前記筐体に取付けられたことを特徴とする請求項１乃至５のいずれかに記載のセンサ装置。
【請求項8】
前記電子式センサの共振点を含む高周波の振動を減衰させるように、前記振動減衰部材の硬度、誘電正接等の物性値、形状、又は寸法が設定されていることを特徴とする請求項１乃至７のいずれかに記載のセンサ装置。

【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は、センシング部の物理的変位に応じて出力される電気信号によって衝突、振動、角速度等を検知可能な電子式センサを搭載したセンサ装置に関するものである。
【０００２】
【従来の技術】
従来より、車両の衝突時にエアバッグの展開を行うために、衝突や振動を検知するための衝突検知センサ装置が車両前部等に搭載されている。そして、従来の衝突検知センサ装置では、例えば、図１６に示す衝突検知センサ装置１０１のように、Ｇセンサ１０２を実装したＰ板（ガラスエポキシ系基板）１０９を、樹脂製の筐体１０３のＧセンサ収容部１０３ａ内にて、筐体１０３に固定されたコネクターミナル１０４にクリンチしてはんだ付けする構造、図１７に示す衝突検知センサ装置２０１のように、Ｐ板１０９を熱かしめすることにより筐体１０３へ固定する構造、図１８に示す衝突検知センサ装置２０１のように、Ｐ板１０９をネジ締めにより筐体１０３へ固定する構造等が採用されている。また、Ｇセンサ１０２は、図示しないセンシング部の変形や移動等の物理的変位に応じて出力される電気信号によって衝突や振動を検出するように構成されており、構造体であるために

必ず共振を発生させる周波数（共振点）が存在している。
【０００３】
【発明が解決しようとする課題】
しかしながら、上述した従来構造の衝突検知センサ装置１０１又は２０１において、共振の原因となる高周波振動が、Ｐ板１０９によってある程度は減衰されるが、その減衰効果は、Ｐ板１０９の材質、サイズ、剛性、Ｇセンサ１０２を含めた重量、及びＰ板１０９を筐体１０３に固定する方法や固定位置によって異なってくる。そして、実際の製品設計においては、Ｐ板１０９の材質、サイズ、剛性、Ｇセンサ１０２を含めた重量は、回路規模によって決定され、Ｐ板１０９を筐体１０３に固定する方法や固定位置は、Ｐ板１０９のサイズによって決定されることになるため、このような構造から得られる高周波振動の減衰効果は成り行き任せとなっていたという問題があった。
【０００４】
そして、Ｐ板１０９に実装されたＧセンサ１０２のセンシング部（図示せず）の共振点が筐体１０３の共振点と重なる場合も想定され、そのような場合には、共振点を含む高周波振動の入力により、筐体１０３の共振にＧセンサ１０２の共振が重畳し、Ｇセンサ１０２は入力Ｇよりも何倍も大きな検出値を出力することとなり、正しい衝突判定を行うことができない事態も生じうる。
【０００５】
また、例えば、図１６に示す従来の衝突検知センサ装置１０１においては、コネクターミナル１０４を筐体１０３側に設けられた筐体１０３にインサートする時点で型精度分の位置ずれが発生し、さらに、Ｐ板１０９をコネクターミナル１０４に組み込む時、組付け性の確保のためにＰ板１０９側の取付け孔とコネクターミナル１０４との間に必ずガタが存在するので、このガタ分の位置ずれが発生することになる（図１６（ｂ）、（ｃ）参照）。例えば、これらの位置ずれによって、車両取付け孔を基準として衝突振動を検知したい方向に対して角度誤差θが存在している場合を考える。図１９（ａ）は水平方向に、図１９（ｂ）は上下方向に角度誤差θが存在している場合をそれぞれ表している。ここで、衝突検知センサ装置１０１に入力される衝突振動をＧ１、Ｇセンサ１０２が実際に検知する衝突振動をそれぞれＧ２とする。Ｇセンサ１０２が衝突検知方向に対しθの角度をもっている場合、Ｇセンサ１０２が実際に検知する衝突振動は、Ｇ２＝Ｇ１×Ｃｏｓθとなるため（図２０参照）、Ｇセンサ１０２の角度誤差θが大きいほど、衝突検知装置１０１の衝突検知能力が低下することになる。
【０００６】
本発明は、上述した問題点に鑑みてなされたものであり、共振の原因となる高周波振動を確実に減衰させ、正確に衝突・振動等を検知することが可能なセンサ装置を提供することを解決すべき課題とする。
【０００７】
【課題を解決するための手段】
この目的を達成するために、請求項１に記載のセンサ装置は、センシング部の物理的変位に応じて電気信号が出力される電子式センサと、その電子式センサが搭載される筐体とを備えたセンサ装置において、前記電子式センサの少なくとも一部分と前記筐体との間に高周波振動を減衰させる振動減衰部材を設けたことを特徴とする。
【０００８】
従って、センシング部の物理的変位に応じて電気信号が出力される電子式センサは高周波帯域（例えば、周波数１ｋＨｚ以上の帯域）に共振点を有するが、電子式センサの少なくとも一部と筐体との間に設けられた振動減衰部材によって、共振の原因となる高周波振動が確実に減衰するので、センサ装置は、共振の影響を受けることなく、衝突、振動、角速度等の正しい検出出力を行うことができる。
【０００９】
また、請求項２に記載のセンサ装置は、前記振動減衰部材が、ポッティング剤からなり、前記電子式センサは、前記ポッティング剤によって覆われたことを特徴とする。

【００１０】
従って、電子式センサを覆うポッティング剤によって、共振の原因となる高周波振動が確実に減衰する。さらに、ポッティング剤によって覆われることで電子式センサの気密性が保持され、湿気や腐食の原因を排除することができるという効果も奏される。尚、ポッティング剤としては、例えば、シリコン系ポッティング剤、ウレタン系ポッティング剤等を好適に用いることができる。
【００１１】
また、請求項３に記載のセンサ装置は、前記振動減衰部材が、板状若しくはシート状の防振材又は前記電子式センサに成形加工された防振材からなり、前記電子式センサは、前記防振材を介して前記筐体に固定されたことを特徴とする。
【００１２】
従って、電子式センサが、板状若しくはシート状の防振材又は前記電子式センサに成形加工された防振材を介して筐体に固定されているため、共振の原因となる高周波振動が防振材によって確実に減衰する。
【００１３】
また、請求項４に記載のセンサ装置は、前記振動減衰部材が、前記電子式センサに少なくとも一部が接続され且つ前記筐体に少なくとも他の一部が固定されたバネ性を有するリード部材からなり、そのリード部材と前記電子式センサの質量とからなるバネ－マス系によって高周波振動を減衰させるように構成されたことを特徴とする。
【００１４】
従って、電子式センサは、バネ性を有するリード部材の少なくとも一部に接続され、そのリード部材の少なくとも他の一部が筐体に固定されることにより支持されているので、リード部材と電子式センサの質量とからなるバネ－マス系によって、高周波振動を確実に減衰させることができる。
【００１５】
また、請求項５に記載のセンサ装置は、前記リード部材が、前記筐体に一体成形されていることを特徴とする。
【００１６】
従って、リード部材が筐体に一体成形されることにより、電子式センサが衝突・振動等の検知方向に対して高精度に位置決めされるので、衝突・振動等を正確に検知することができる。
【００１７】
また、請求項６に記載のセンサ装置は、前記電子式センサが、検知部、通信部、電源回路等が１パッケージ化されて、前記筐体に直付けされたことを特徴とする。
【００１８】
従って、電子式センサが検知部、通信部、電源回路等が１パッケージ化されて、基板を用いることなく筐体に直付けされているため、組付け工数の低減、部品点数の削減によるコストダウンを図ることができる。また、電子式センサが筐体に直付けされることにより振動伝達が直接的となるため、振動減衰部材により高周波振動を減衰させることは極めて重要である。
【００１９】
また、請求項７に記載のセンサ装置は、前記電子式センサが基板上に実装され、その基板を介して前記筐体に取付けられたことを特徴とする。
【００２０】
従って、基板上に実装された電子式センサと筐体との間に設けられた振動減衰部材によって、共振の原因となる高周波振動が確実に減衰する。
【００２１】
また、請求項８に記載のセンサ装置は、前記電子式センサの共振点を含む高周波の振動を減衰させるように、前記振動減衰部材の硬度、誘電正接等の物性値、形状、又は寸法が設定されていることを特徴とする。

【００２２】
従って、振動減衰部材の硬度、誘電正接等の物性値、形状、又は寸法を適切に設定することにより、電子式センサの共振点を含む高周波の振動を確実に減衰させることができる。また、筐体の外形寸法、形状等を変更することなく、筐体の振動伝達特性を所望の特性とすることが可能となるため、筐体外形を統一することができ、筐体のコストダウンが図られ、さらに搭載設計の手間が省ける等の効果が奏される。
【００２３】
【発明の実施の形態】
以下、本発明のセンサ装置を具体化した衝突検知センサ装置の各実施形態について図面を参照しつつ説明する。
【００２４】
最初に、第一の実施形態の衝突検知センサ装置（以下、センサ装置と称する）１について、図１を参照しつつ説明する。センサ装置１は、Ｇセンサ２と、筐体３とを主体として構成され、車両の前部等に搭載されて衝突を検知し、エアバッグ制御装置へ衝突検知信号を出力するためのセンサ装置である。
【００２５】
Ｇセンサ２は、図示しないセンシング部（検知部）を備え、加速度（以下、単に”Ｇ”とも称する）が入力されると、センシング部に物理的変位（移動、変形等）が生じ、その変位量に応じた電気信号を出力するように構成されている。ここで、Ｇセンサ２は、全ての範囲の入力Ｇについて検出可能であることが理想的であるが、実際には、図２に示すように有限のダイナミックレンジ（検出可能な入力Ｇの範囲）を有しており、ダイナミックレンジを超える入力加速度が印加されると正しく検出することができない。また、Ｇセンサ２は、構造体であることから必ず共振点（共振周波数とも称する）を有している。よって、入力加速度の中にＧセンサ２の共振点周波数成分が含まれていると、Ｇセンサ２の検知部は、Ｇセンサ２のダイナミックレンジを超える働きをすることがあり、この時、Ｇセンサ２は正しい検知ができなくなる。尚、Ｇセンサ２としては、例えば、センシング部の移動量によって加速度を検出するように構成された櫛歯式のＧセンサ等を用いることができる。また、本実施形態のＧセンサ２は、検知部、通信部、電源回路等が１パッケージ化されている。
【００２６】
筐体３は、Ｇセンサ２が搭載される樹脂成型部品であり、例えば、ＰＢＴ（ポリブチレンテレフタレート）樹脂、ナイロン樹脂等によって形成される。筐体３には、下面側に開口するＧセンサ収容部３ａが形成されると共に、Ｇセンサ２を外部に電気的接続するためのコネクターミナル４と、車両取付け用のボルトが挿通される円筒状の金属ブッシュ６とが埋設されている。また、コネクターミナル４の一部はＧセンサ収容部３ａ内にて露出し、Ｇセンサ２は、Ｇセンサ収容部３ａ内でコネクターミナル４にはんだ付け等により固定されると共に電気的接続が図られている。
【００２７】
コネクターミナル４は、図示しない導体を介して図示しないエアバッグ制御装置に電気的に接続されており、Ｇセンサ２からの出力信号がエアバッグ制御装置に入力されるようになっている。エアバッグ制御装置は、Ｇセンサ２からの出力信号に基づいて、図示しないエアバッグの展開制御を行う。
【００２８】
さらに、筐体３のＧセンサ収容部３ａ内には、ポッティング剤５が封止されている。すなわち、Ｇセンサ収容部３ａにおいてコネクターミナル４にはんだ付けされたＧセンサ２は、ポッティング剤５によって周囲が覆われ、Ｇセンサ２と筐体３のＧセンサ収容部３ａを形成する内壁とによって形成される空間にはポッティング剤５が充填されている。尚、ポッティング剤５としては、例えば、シリコン系ポッティング剤、ウレタン系ポッティング剤等を使用することができる。
【００２９】

そして、センサ装置１は、筐体３に埋設された金属ブッシュ６にボルトが挿通され、車両側取付け部に対して締付け固定される。

【００３０】

次に、上述した構成を有するセンサ装置１において衝突を検知する場合の各部の作用について図面を参照しつつ説明する。

【００３１】

車両の衝突等によってセンサ装置１に入力される振動は、あらゆる周波数成分により構成されている。この周波数成分は、図３に示すように、車両の衝突判定に必要な成分（主に低周波帯域、例えば周波数１ｋＨｚ未満）と、衝突判定に不要な成分（主に高周波帯域、例えば周波数１ｋＨｚ以上）とに二分することができる。また、Ｇセンサ２（より詳細には、センシング部）の共振点は、高周波帯域に属しており、筐体３の共振点はＧセンサ２の共振点とは異なる周波数に設定されている（図３では、Ｇセンサ２の共振点よりも低く設定した例を示す）。尚、衝突判定に必要な周波数帯では、筐体の振動伝達の共振・減衰が無いことが必須条件であり、Ｇセンサの共振が始まる周波数以上では、Ｇセンサ２に入力する加速度がＧセンサ２の低周波数側の検知に影響ないレベルに減衰していることが必須条件である。また、筐体の共振点はＧセンサの共振点よりも低く設定されているため、筐体共振点付近の周波数帯では筐体の共振が生じても構わない。

【００３２】

次に、衝突による衝突Ｇ振動入力からセンサ出力までの流れについて、図４乃至図６を参照しつつ説明する。衝突Ｇ振動は、図６（ａ）に示すように、低周波振動（太線で示す）に高周波振動（細線で示す）が重畳して構成されている。そして、車両を介してセンサ装置１に振動が伝達されると、図５に示すように、Ｇセンサ収容部３ａに封止されたポッティング剤５によってＧセンサ２の共振点を含む高周波の振動が減衰され、図６（ｂ）に示すように、衝突判定に必要な低周波振動のみがＧセンサ２に伝達される。そして、図６（ｃ）に示すように、Ｇセンサ２にダイナミックレンジ内の低周波振動のみが伝達され、Ｇセンサ２から正しいＧ検出信号が出力される。これにより、エアバッグ制御装置では正しいＧ検出信号に基づいて正確に衝突状態を判定し、適切にエアバッグの展開制御を行うことができる。

【００３３】

ここで、比較のため、従来のセンサ装置において振動伝達が不適当な場合を図６（ｄ）に示す。図６（ｄ）から明らかなように、高周波振動によりＧセンサが共振し、特定周波数の振動が増幅されている。このため、Ｇセンサのダイナミックレンジを超えた振動が伝達されるため、正しいＧ検出信号を得ることができなかった。

【００３４】

尚、Ｐ板（ガラスエポキシ系基板）を用いることなくＧセンサ２を筐体３側に固定する本実施形態で採用される構造は、Ｐ板を介してＧセンサを筐体に固定する構造（図１２及び１３に示す従来構造）と比較して、筐体からＧセンサへの振動伝達がより直接的となるため、上述したようにＧセンサ２をポッティング剤５で覆うことにより高周波振動を減衰させることは極めて重要である。

【００３５】

さらに、本実施形態によれば、Ｇセンサ２がポッティング剤５によって覆われることで気密性が保持され、湿気や腐食の原因を排除することができるという効果も奏される。

【００３６】

次に、本発明の第二の実施形態の衝突検知センサ装置５１について、図７～１０を参照しつつ説明する。尚、第一の実施形態と同一の構成については同一符号を付し、これらについての詳細説明を省略する。

【００３７】

前記第一の実施形態では筐体３のセンサ収容部３ａ内にポッティング剤５を封止することにより高周波振動を減衰させる構造であったが、本実施形態では、ポッティング剤５の封止に代えて、板状若しくはシート状に加工又はＧセンサ２に成形加工された防振材５５を

介してＧセンサ２を筐体３に固定することにより高周波振動を減衰させる構造としたものである。

【００３８】

すなわち、図７に示すように、筐体３には下向きに開口するセンサ収容部３ａが形成され、センサ収容部３ａ内壁面に、板状又はシート状の防振材５５が一の面にて接着固定され、さらに防振材５５の反対側の面（図では下面）にＧセンサ２が接着固定されている（或いは、Ｇセンサ２に成形加工された防振材５５を筐体３に接着固定してもよい）。防振材５５は、高周波振動を減衰可能な弾力性材料からなり、例えば、シリコン系ゴム等を好適に用いることができる。コネクターミナル４とＧセンサ２とは、ワイヤボンディング５７によって連結され、電気的接続が図られている。さらに、センサ収容部３ａの開口部は、樹脂材料からなる板状のリッド５８により塞がれている。

【００３９】

本実施形態によれば、Ｇセンサ２を、防振材５５を介して筐体３に固定する構造とすることにより、高周波振動を確実に減衰させ、上述した第一の実施形態と同様の効果を奏することができる（図４～６参照）。

【００４０】

また、本実施形態は、図８に示すように、Ｇセンサの質量Ｍと、防振材のバネ定数Ｋと、防振材の減衰項Ｃとからなるモデルを想定することが可能であり、防振材５５の硬度、誘電正接（Ｔａｎδ）等の物性値、厚さ等の寸法、又は形状を適宜変更して防振材のバネ定数及び減衰項を変更することにより、筐体の共振点（共振周波数）や共振ピークを所望の範囲内に設定することが可能である。例えば、図９（ａ）に示すように、防振材５５の硬度を変更することにより、共振点を移動させることができる。すなわち、防振材５５の硬度を大きくすると共振点が高くなり（図９（ａ）では共振点が右に移動）、硬度を小さくすると共振点が低くなる（図９（ａ）では共振点が左に移動）。また、図９（ｂ）に示すように、防振材５５の誘電正接（Ｔａｎδ）を大きくすることにより、共振ピークを下げることができる。さらに、図９（ｃ）に示すように、防振材５５の厚さを変更することにより、共振点を移動させることができる。従って、本実施形態によれば、図１０に示すように、筐体３の外形寸法、形状等を変更することなく、筐体３のＧ伝達特性を所望の特性とする（すなわち、防振材５５を含めた筐体３の共振点をＧセンサ２の共振点よりも低い周波数とし、且つ共振ピークを下げる）ことが可能となるため、筐体外形を統一することができ、筐体のコストダウンが図られ、さらに搭載設計の手間が省ける等の利点が得られる。

【００４１】

次に、第二の実施形態の変形例について、図１１を参照しつつ説明する。前記第二の実施形態では、検知部、通信部、電源回路等が１パッケージ化されたＧセンサ２を防振材５５に直接、接着固定する構造であったが、本変形例のセンサ装置６１では、Ｇセンサ２をＰ板（ガラスエポキシ系基板）６９上に実装し、筐体３のＧセンサ収容部３ａの内壁面に防振材５５を一の面にて接着固定し、防振材５５の反対側の面に、Ｇセンサ２を実装したＰ板６９を接着固定する構造としたものである。本変形例においても、前記第二の実施形態と同様の効果が奏される。

【００４２】

次に、本発明の第三の実施形態の衝突検知センサ装置７１について、図１２～１４を参照しつつ説明する。尚、前記各実施形態と同一の構成については同一符号を付し、これらについての詳細説明を省略する。

【００４３】

前記第二の実施形態では、板状若しくはシート状に加工又はＧセンサ２に成形加工された防振材５５を介してＧセンサ２を筐体３に固定することにより高周波振動を減衰させる構造であったが、本実施形態では、これに代えて、図１２に示すように、Ｇセンサ２に一端が接続され且つ筐体３に他端が固定されたバネ性を有する複数のリード７５とＧセンサ２の質量とからなるバネ－マス系によって高周波振動を減衰させるように構成したものであ

る。尚、リード７５が、本発明のリード部材を構成するものである。
【００４４】
すなわち、図１２に示すように、衝突検知センサ装置７１において、Ｇセンサ２は、後方側（図１２ではＧセンサ２の左）に設けられた２本のリード７５と前方側（図１２ではＧセンサ２の右）に設けられた１本のリード７５を介して筐体３に取付けられている。リード７５は、金属材料からなり、長手方向略中央部にベント部が形成されたバネ性を有する部材である。各リード７５の一端は、それぞれろう付け又ははんだ付けによりＧセンサ２に接合されている。また、各リード７５の他端は、筐体３に一体成形（インサート成形）されることにより、それぞれ筐体３に固定されている。さらに、後方側のリード７５は、他端がコネクターミナル４に溶接にて接合されることにより電気的導通が図られている。従って、Ｇセンサ２を成形型内で位置決めすることができるので、極めて高精度に位置決めを行うことができる。また、コネクターミナル４、リード７５、Ｇセンサ２がインサート成形された筐体３は、内部気密性を保持するために、リッド７６によって上下が塞がれる構造となっており、リッド７６は、筐体３にシール、レーザ溶着等で固定される。
【００４５】
ここで、リード７５とＧセンサ２とは、図１３に模式図に示されるバネ－マス系を形成しており、そのバネ－マス系の固有振動数を持つことになる。すなわち、リード７５がバネ－マス系におけるバネの役割を果たし、Ｇセンサ２が質量として作用する。このバネ－マス系の固有振動数ｆｎは、数式１～４によって導かれる数式５によって表される。尚、ｌは、両端単純支持のはりの長さを、ｍは、はりの中央に設けたおもりの質量を、ＥＩは、はりの曲げ剛性（Ｅ：弾性係数、Ｉ：断面二次モーメント）をそれぞれ表している。
【００４６】
すなわち、はり中点のたわみδは、数式１により表される。
【００４７】
【数１】

$$\delta = \frac{Pl^3}{48EI}$$

【００４８】
数式１の変形により、はりのバネ定数ｋは、数式２のように表される。
【００４９】
【数２】

$$k = \frac{P}{\delta} = \frac{48EI}{l^3}$$

【００５０】
また、はり中点における曲げ変位をｘとしたとき、数式３の関係が成立する。
【００５１】
【数３】

$$m\ddot{x} + kx = 0$$

【００５２】
よって、数式３へ数式２を代入することにより、数式４が得られる。
【００５３】
【数４】

$$\ddot{x} + \frac{48EI}{ml^3}x = 0$$

【００５４】
従って、固有振動数ｆｎは、以下の数式５によって求められる。
【００５５】

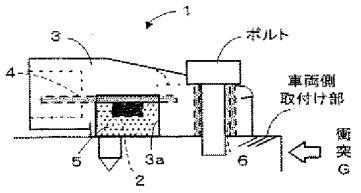
【数５】

$$fn=\frac{\omega n}{2\pi}=\frac{1}{2\pi}\sqrt{\frac{48EI}{ml^3}}$$

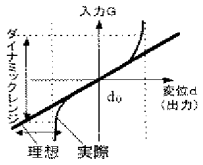
【００５６】
そして、バネ－マス系の固有振動数ｆｎが上述した数式５によって表されることから、曲げ剛性ＥＩを変更することによって、或いは、Ｇセンサ２の質量ｍを変更することによって、固有振動数ｆｎをコントロールすることができる。また、曲げ剛性ＥＩを小さくする方法としては、（１）リード７５に弾性係数が小さい材料を使用する、（２）リード７５の断面二次モーメントを小さくする（断面形状の変更）、（３）リード７５にベントを設ける等が考えられる。
【００５７】
ここで、リード７５とＧセンサ２とからなるバネ－マス系による振動伝達特性は、図１４に示すグラフのように表される。バネ－マス系の固有振動数をｆｎとすると、ｆｎ×√２で振動伝達率は必ず１になり、ｆｎ×√２よりも大きい周波数では、減衰が始まる。よって、振動減衰させたい周波数をｆｘとすると、図１４にて示すグラフで表される関係（周波数ｆｘで振動伝達率が１未満）となるように、バネ－マス系の固有振動数ｆｎを調整すればよい。
【００５８】
さらに、バネ－マス系における振動のＱ値を変化させることで、振動減衰量を変化させることも可能である。尚、図１４において、実線のグラフはバネ－マス系のＱ値が相対的に高い場合であり、破線のグラフはＱ値が相対的に低い場合を表している。例えば、図１５に示す第三の実施形態の変形例である衝突検知センサ装置７１’のように、Ｇセンサ２が収納される筐体３の内部空間にポッティング剤５を充填することにより、Ｑ値を変化させることができる。尚、図１５（ａ）は、衝突検知センサ装置７１’を側方から視た状態を表す概略構成図であり、（ｂ）は（ａ）におけるＢ－Ｂ線断面図である。
【００５９】
尚、本発明は上述した各実施形態に限定されるものではなく、本発明の主旨を逸脱しない範囲で種々の変更を施すことが可能である。
【００６０】
例えば、高周波振動を減衰させる構造は上述した各実施形態の構造に限定されるものではなく、要するに、Ｇセンサの少なくとも一部と筐体との間に高周波振動を減衰させる振動減衰部材を設ける構造とすればよいのである。
【００６１】
また、前記各実施形態では、本発明を加速度や振動を検出するための衝突検知センサ装置に適用した例を示したが、例えば、角速度を検出するためのロールオーバーセンサ、ロールレートセンサ、ヨーレートセンサ等に適用することも可能である。要するに、センシング部の物理的変位に応じて電気信号が出力される電子式センサと、その電子式センサが搭載される筐体とを備えたセンサ装置に本発明を適用することが可能である。
【００６２】
また、前記第二の実施形態の変形例ではＧセンサ２をＰ板（ガラスエポキシ系基板）６９上に実装したが、セラミック基板上に実装する構成としてもよい。
【００６３】
【発明の効果】
以上述べたように本発明のセンサ装置によれば、センシング部の物理的変位に応じて電気信号が出力される電子式センサの少なくとも一部と筐体との間に設けられた振動減衰部材によって、共振の原因となる高周波振動が確実に減衰するので、センサ装置は、共振の影響を受けることなく、衝突、振動、角速度等の正しい検出出力を行うことができる。
【図面の簡単な説明】

【図１】本発明の第一の実施形態における衝突検知センサ装置を側方から視た状態を表す概略構成図である。
【図２】ＧセンサのＧ検出出力特性の一例を示すグラフである。
【図３】Ｇセンサ及び筐体における振動伝達率と振動周波数との関係を示すグラフである。
【図４】衝突Ｇ振動入力からセンサ出力までの流れを示す説明図である。
【図５】ポッティング剤封止前後における筐体の振動伝達特性の変化を示すグラフである。
【図６】（ａ）は衝突Ｇの入力波形の一例を示すグラフを、（ｂ）はポッティング剤によって高周波振動が減衰した振動波形の一例を示すグラフを、（ｃ）はＧセンサに入力される振動波形の一例を示すグラフを、（ｄ）は従来のセンサ装置において振動伝達が不適当であった場合のＧセンサに伝達される振動波形の一例を示すグラフをそれぞれ示している。
【図７】第二の実施形態における衝突検知センサ装置を側方から視た状態を表す概略構成図である。
【図８】Ｇセンサと防振材とからなるモデルを示す説明図である。
【図９】（ａ）は防振材の硬度を変化させた場合の筐体の共振点の変化を、（ｂ）は防振材の誘電正接を変化させた場合の筐体の共振ピークの変化を、（ｃ）は防振材の厚さを変化させた場合の筐体の共振点の変化をそれぞれ示すグラフである。
【図１０】防振材使用の有無による筐体の振動伝達特性の変化を示すグラフである。
【図１１】第二の実施形態の変形例における衝突検知センサ装置を側方から視た状態を表す概略構成図である。
【図１２】（ａ）は、第三の実施形態における衝突検知センサ装置を側方から視た状態を表す概略構成図であり、（ｂ）は（ａ）におけるＡ－Ａ線断面図である。
【図１３】リードとＧセンサとからなるバネ－マス系を説明するための模式図である。
【図１４】リードとＧセンサとからなるバネ－マス系の振動伝達特性の一例を示すグラフである。
【図１５】（ａ）は、第三の実施形態の変形例における衝突検知センサ装置を側方から視た状態を表す概略構成図であり、（ｂ）は（ａ）におけるＢ－Ｂ線断面図である。
【図１６】従来技術における衝突検知センサ装置の一例を示す概略構成図であり、（ａ）は、衝突検知センサ装置を側方から視た状態を表す概略構成図であり、（ｂ）は（ａ）におけるＣ－Ｃ線断面図であり、（ｃ）はＰ板のコネクターミナル取付け孔付近を示す拡大図である。
【図１７】従来技術における衝突検知センサ装置の他の一例を示す概略構成図である。
【図１８】従来技術における衝突検知センサ装置のさらに他の一例を示す概略構成図である。
【図１９】従来技術の衝突検知センサ装置においてＧセンサに取付け角度誤差がある場合を説明する図であり、（ａ）は水平方向に、（ｂ）は上下方向に角度誤差がある場合をそれぞれ表している。
【図２０】Ｇセンサに取付け角度誤差がある場合において入力される衝突振動と実際に検知される衝突振動との関係を表す図である。
【符号の説明】
１，５１，６１，７１，７１’…衝突検知センサ装置（センサ装置）、２…Ｇセンサ（電子式センサ）、３…筐体、５…ポッティング剤（振動減衰部材）、５５…防振材（振動減衰部材）、６９…Ｐ板（基板）、７５…リード（リード部材、振動減衰部材）。

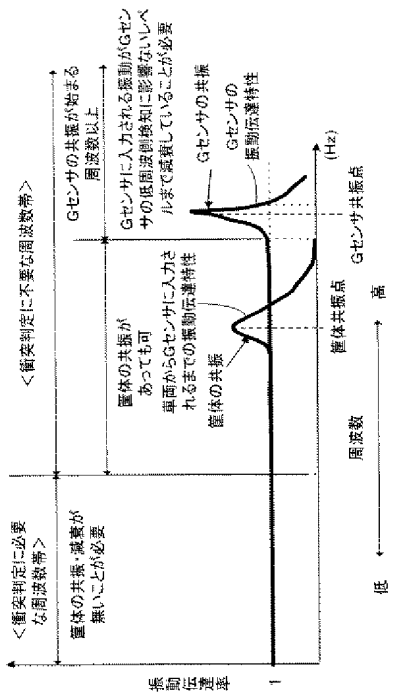
【図1】



【図2】



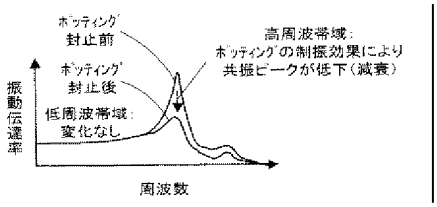
【図3】



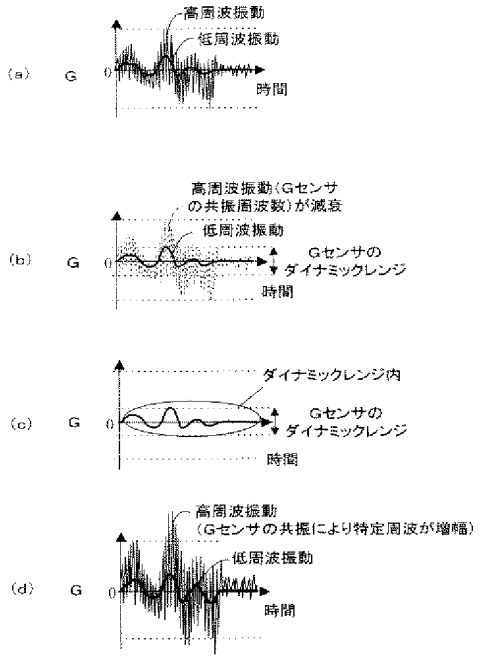
【図4】



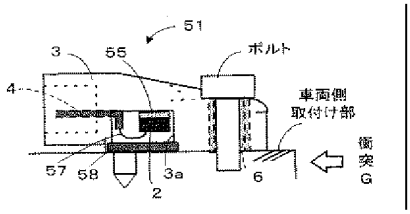
【図5】



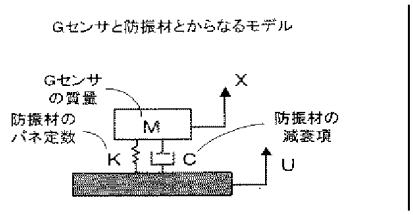
【図6】



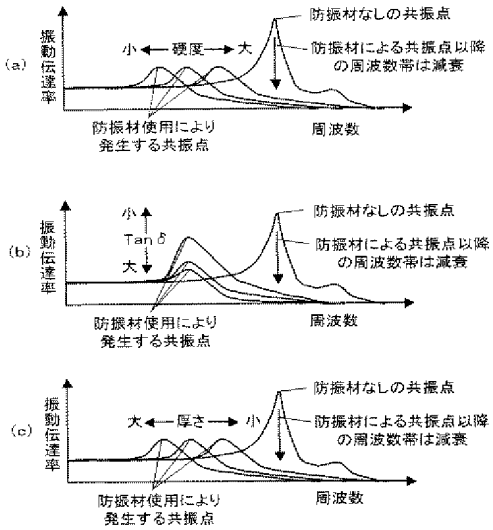
【図7】



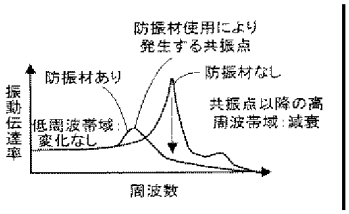
【図8】



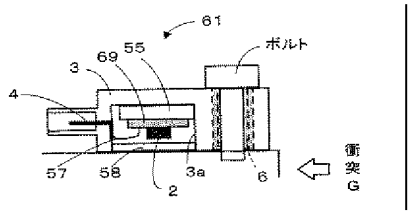
【図9】



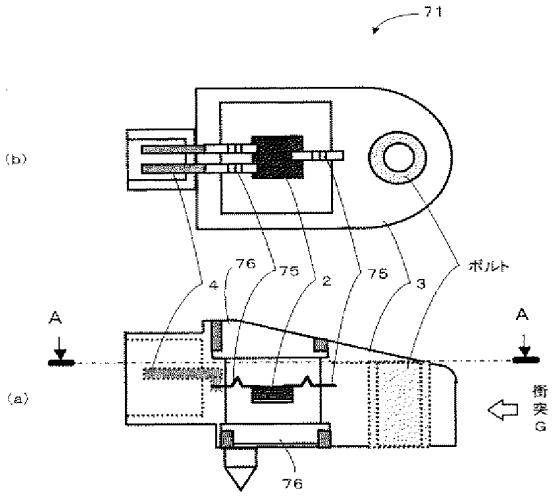
【図10】



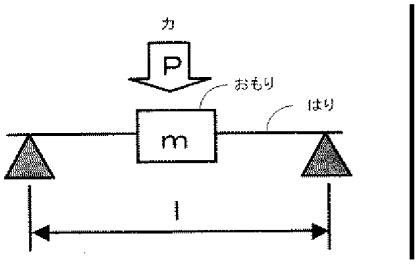
【図11】



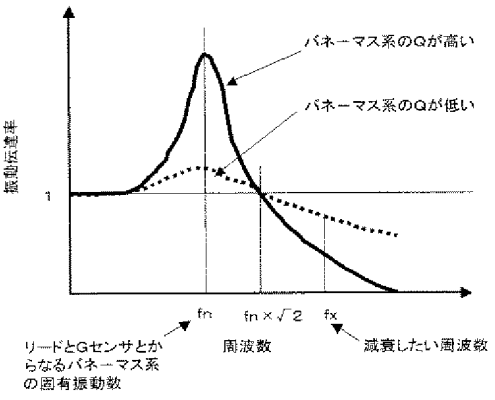
【図12】



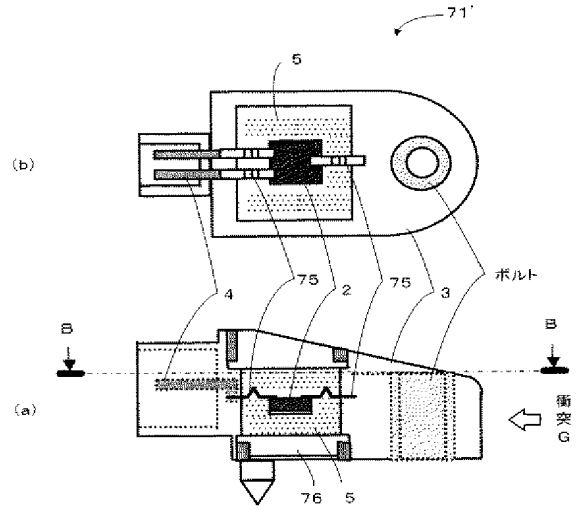
【図13】



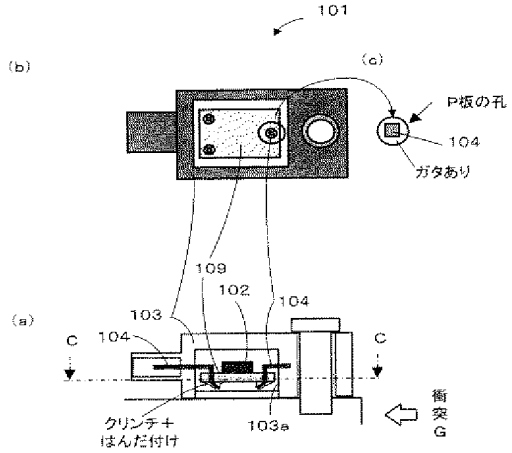
【図14】



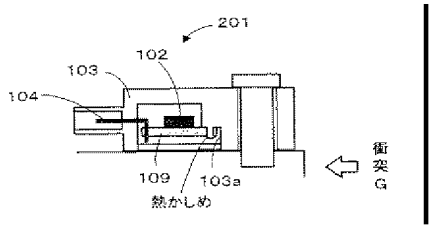
【図15】



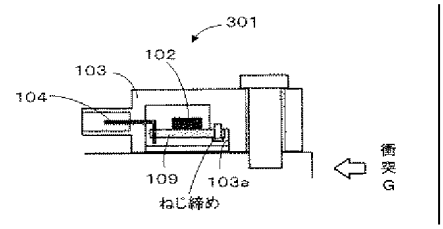
【図16】



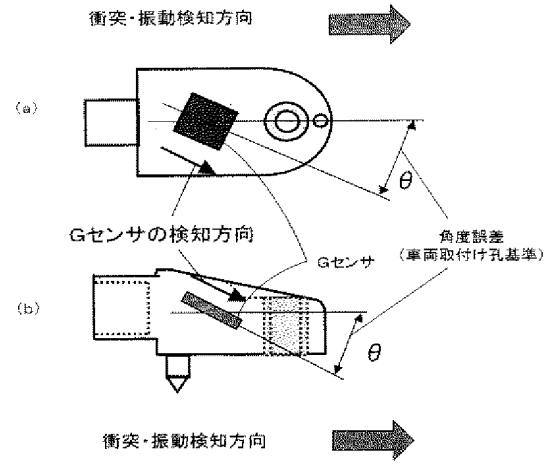
【図17】



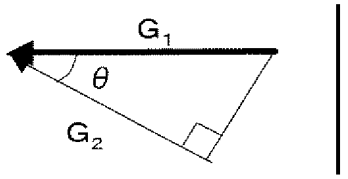
【図18】



【図19】



【図20】



Europäisches Patentamt
European Patent Office
Office européen des brevets

Patent Translate
Powered by EPO and Google

Notice

This translation is machine-generated. It cannot be guaranteed that it is intelligible, accurate, complete, reliable or fit for specific purposes. Critical decisions, such as commercially relevant or financial decisions, should not be based on machine-translation output.

DESCRIPTION JP2009210301

PROBLEM TO BE SOLVED: To detect abnormality of a rolling device with high accuracy. SOLUTION: The rolling device includes an acceleration sensor 11 attached to one of the first raceway member and the second raceway member and outputting a voltage corresponding to the acceleration at the time of vibration, an output voltage value of the acceleration sensor 11 , And a low-pass filter 13 for attenuating the set frequency component of the output voltage of the amplifier 12. The low pass filter 13 performs eight times the specific frequency geometrically calculated when the rolling element moves in the rolling element circulation path in accordance with the relative movement between the first race member and the second race member, Preferably, it attenuates frequencies greater than 6 times. BACKGROUND OF THE INVENTION

Rolling device and abnormality detection method for rolling device

[0001]

TECHNICAL FIELD The present invention relates to a rolling device that arranges a plurality of rolling elements in a rolling path provided between race members and relatively moves the race members, and an abnormality detection method that detects abnormality of such a rolling device.

[0002]

For example, when a defect occurs in the raceway surface of a rolling bearing for some reason, each time a rolling element passes through it, a shock is generated and vibration occurs.

Various methods have been conventionally proposed for measuring vibrations from a device or a rolling element generated in this way and determining an abnormality based on the measured change in vibration. However, in either case, since an abnormality is judged within a general measuring frequency range, abnormality can not be detected with high accuracy.

[0003]

For example, in Patent Document 1, in order to detect an abnormality of a rolling bearing, the lower limit side of the measurement frequency range is set to 9 kHz to 10 kHz, the upper limit side of the measurement frequency range is set to 25 kHz to 30 kHz based on the characteristics of the acceleration detector There. Then, the measured vibration acceleration is frequency analyzed, and an abnormality is detected based on the peak value of the frequency spectrum obtained from the analysis result. Also, as a method not requiring such frequency analysis, Patent Document 2 sets the measurement frequency range of general mechanical equipment to 20 kHz to 50 kHz. Then, the cumulative frequency distribution of the absolute value of the vibration waveform is obtained, and the abnormality is diagnosed based on the equivalent effective value, the maximum value of the vibration waveform, and the magnitude of the peak ratio.

[0004]

Here, a vibration sensor is used as a sensor for detecting vibration. Patent Document 3 discloses such a vibration sensor. In Patent Document 3, a technique for detecting vibration in a ball screw with a vibration sensor is disclosed. As such a vibration sensor, a piezoelectric type acceleration sensor (acceleration pickup) which is compact, easy to handle, and has a wide detection frequency band and wide dynamic range is widely used. This vibration sensor converts vibration (acceleration, speed, displacement) into an electric signal, and roughly includes a charge output type acceleration pickup and an amplifier built-in piezoelectric acceleration pickup. The charge output type acceleration pickup is a charge output type pickup for outputting the detected vibration as a charge, and converts the output electric charge into a voltage by a charge amplifier. In addition, the built-in amplifier type piezoelectric acceleration pickup outputs the detected vibration as a voltage. Patent Document 1: JP-A-61-288126 Patent Document 2: JP-A-2001-304954 Patent Document 2: JP-A-2001-349407

[0005]

By the way, if it is tried to detect an abnormality with a general measurement frequency range as in Patent Document 1 or Patent Document 2, even if abnormality (vibration indicating abnormality) occurs, There is a problem that it is hidden by noise and misses occurring abnormality. In particular, in the case of a rolling device such as a ball screw or a linear motion guide bearing device, the rolling elements are different from rolling devices such as rolling bearings arranged at substantially constant intervals and always in a substantially constant constrained state Since there are specific problems, such a tendency was remarkable.

[0006]
An object of the present invention is to detect an abnormality of a rolling device with high accuracy.

[0007]
In order to solve the above problem, a rolling device according to a first aspect of the present invention comprises a first race member, a second race member and a plurality of rolling elements, wherein the first race member and the By rollingly inserting the rolling elements in at least one rolling element circulation path constituted by the raceway grooves provided in the respective raceway members and the return path provided in one of the raceway members , The first race member and the second race member are moved relative to each other, the rolling device being mounted on one of the first race member and the second race member and having a voltage An amplification means for amplifying an output voltage of said acceleration sensor, and filter means for attenuating a set frequency component concerning an output voltage of said acceleration sensor or an output voltage of said amplification means, wherein said filter means , The relative movement between the first race member and the second race member exceeds eight times the specific frequency geometrically calculated when the rolling element moves in the rolling element circulation path And the frequency is attenuated.

[0008]

According to a second aspect of the present invention, in the rolling device of the first aspect, the filter means has a damping characteristic of 20 dB / dec or more.

According to a third aspect of the present invention, there is provided the rolling device according to the first aspect, wherein the filter means includes a calculation pass frequency of the rolling element and a calculated pass frequency of the rolling element On the other hand, it is

characterized in that at least one of the 4 times, 6 times and 8 times frequency is attenuated with an attenuation characteristic of 6 dB / oct or more.

[0009]

A rolling apparatus according to a fourth aspect of the present invention is the rolling device according to any one of the first to third aspects, wherein the frequency characteristic of the acceleration sensor is substantially linear over 10 KHz , The amplifying means performs nonlinear output based on the output voltage from the acceleration sensor.

A rolling device according to a fifth aspect of the present invention is the rolling device according to any one of the first to fourth aspects, wherein the filter means is a mechanical filter made of an elastic body It is characterized by being there.

[0010]

A rolling device according to a sixth aspect of the present invention is the rolling device according to any one of the first to fifth aspects, wherein the raceway groove of the first race member and the second race member Of the raceway grooves are Gothic arch shapes. A rolling device according to a seventh aspect of the present invention is the rolling device according to any one of the first to sixth aspects, wherein the first and second raceway members and the rolling elements , And is formed of metal or ceramic.

[0011]

According to a ninth aspect of the present invention, there is provided a method of detecting abnormality in a rolling device, wherein the first race member and the second race member of the rolling device according to any one of the first to seventh aspects , And detects abnormality of the rolling device from the detected value, characterized by monitoring a vibration of a specific frequency and monitoring vibration of the rolling device An abnormality is detected.

[0012]

According to the first and eighth aspects of the invention, in the rolling device, by attenuating

frequencies exceeding 8 times with respect to a specific frequency, it is possible to accurately detect the vibration of the monitored object, correct the abnormality of the monitored object accurately .

According to the third aspect of the invention, filtering can be performed by taking individual events into consideration, so that the vibration of the monitoring target can be detected more accurately. According to the fifth aspect of the invention, the filter means can be constructed easily.

[0013]

Also, when the raceway groove is formed in a Gothic arch shape, it is impossible to super-finish shaking the grinding wheel left and right, so that it is inevitable that vibration occurs due to the unevenness when the rolling element rolls in the raceway groove . According to the sixth aspect of the present invention, it is possible to lower the output voltage corresponding to the vibration of the frequency which is not subject to monitoring of the vibration detection occurring in such a case, that is, the detection sensitivity can be lowered. In addition, when the raceway member and the rolling element are formed of metal or ceramic, it is inevitable that vibration occurs due to the unevenness when the rolling element rolls in the raceway groove. According to the seventh aspect of the present invention, it is possible to lower the output voltage corresponding to the vibration of the frequency not to be monitored for the vibration detection occurring in such a case, that is, to lower the detection sensitivity.

[0014]

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS Preferred embodiments of the present invention (hereinafter referred to as embodiments)) Will be described in detail with reference to the drawings. (First Embodiment) First, a first embodiment will be described. (Configuration) The first embodiment is an acceleration pickup constituting a vibration sensor, and FIG. 1 shows the configuration of the acceleration pickup 10. As shown in FIG. 1, the acceleration pickup 10 is a built-in amplifier type piezoelectric acceleration pickup. That is, the acceleration pickup 10 includes a piezoelectric type acceleration sensor 11 that outputs a voltage corresponding to the acceleration at the time of vibration, an amplifier 12 that amplifies the output voltage value of the acceleration sensor, and a low pass filter 13 that is an electric filter . Here, the acceleration sensor 11 is a so-called bimorph type piezoelectric acceleration sensor in which two piezoelectric elements that extend and contract in the length direction are joined and

one of them flexes when the other piezoelectric element expands. The characteristics of the acceleration sensor 11 are determined, for example, in the maximum output voltage range or the output voltage range with the acceleration 1 G when the vibration frequency is 1 KHz. For example, the output voltage range is ± 5 V.

[0015]

The low-pass filter 13 filters (filters) an oscillation frequency band (oscillation frequency component) that is equal to or greater than the natural frequency of the object to be measured or the object to be monitored (the track member or the rolling element member of the rolling device) to which the acceleration pickup 10 is attached . Specifically, the low-pass filter 13 filters the frequency band that is n times larger than the specific frequency obtained from the measured object to which the acceleration pickup 10 is attached. Here, the specific frequency is, for example, the calculated pass frequency of the rolling element calculated by the following formulas (1) to (3). In addition, n times is 8 times, preferably 6 times. The expressions (1) to (3) are equations in which the rolling device corresponds to the ball screw. (1 - (Dw · cos α · cos <2> β / dm)) · fr / 2 [Hz] · · · (1) z · fi = z · (1+ (Dw · cos α · cos <2> β / dm)) · fr / 2 [Hz] (2) 2 · fb = 2 · (dm / (Dw · cos <2> α · cos <2> β) - (Dw · cos <2> α · cos <2> β / dm)) · fr / 2 [Hz] (3)

[0016]

Here, z is the number of loaded balls per lead (z = π · dm / (Dw · cos β)). Also, fc is the revolution frequency [Hz] of the ball. In other words, fc is the frequency at which one rolling element revolves by one lead, indicating the motion of the rolling element with respect to the nut. Fi is the relative rotational frequency [Hz] of the screw shaft with respect to the revolution frequency of the ball. In other words, fi is the frequency at which the screw shaft revolves by one lead with reference to the revolution frequency fc of the ball, and indicates the movement of the shaft with respect to the rolling element. Fb is the rotation frequency of the ball [Hz], and fr is the shaft rotation frequency [Hz]. Also, Dw is the ball diameter [mm], dm is the ball pitch diameter [mm], α is the contact angle [°] and β is the lead angle [°].

[0017]

The frequencies calculated by the equations (1), (2) and (3) are highly correlated with the site of damage occurrence in the ball screw. From these facts, it is possible to know which part has been

damaged by the increase of the spectrum peak of the frequency calculated by each formula. Specifically, in the formula (1), it is possible to know the damage (the frequency at the time of damage) to be applied to the nut by the ball, and in the expression (2), the damage to the shaft (frequency at the time of damage) is known by the ball, In the formula, damage to the ball (frequency at the time of damage) is known. The largest one of the values obtained by the above formulas (1) to (3) is set as a specific frequency.

[0018]

The low pass filter 13 filters and outputs the frequency band of 8 times, preferably 6 times the calculated passing frequency of the rolling element calculated based on the above-mentioned formulas (1) to (3). The low-pass filter 13 has an attenuation characteristic of 20 dB / dec or more. FIG. 2 shows its attenuation characteristic. FIG. 3 shows an example of the configuration of the low-pass filter 13 that realizes such attenuation characteristics.

[0019]

4 to 7 show an installation example of the acceleration pickup 10 (vibration sensor). As shown in FIG. 4, the acceleration pickup 10 is attached to the outer peripheral surface of the flange portion 32 a of the nut 32 of the ball screw 30. Further, as shown in FIG. 5, the acceleration pickup 10 is attached to the side surface facing the moving direction of the flange portion 32 a of the nut 32. Further, as shown in FIG. 6, the acceleration pickup 10 is mounted on a side surface of the linear guide (linear motion guide device) 90 which is composed of the guide rail 91 and the slider 92 and is parallel to the moving direction of the slider 92. Further, as shown in FIG. 7, the acceleration pickup 10 is attached to the side surface facing the moving direction of the slider 92.

[0020]

(Operation, Operation and Effect) Operation, operation and effect are as follows. As shown in the examples of FIGS. 4 to 7, the acceleration pickup 10 is attached to the track member (the nut 32 and the slider 92). As a result, in the acceleration pickup 10, the acceleration sensor 11 outputs a signal according to the vibration (acceleration) generated in the track member by the movement of the track member. Then, the amplifier 12 amplifies the output signal of the acceleration sensor 11 and outputs it to the low-pass filter 13. The low-pass filter 13 filters the signal from the

amplifier 12 and outputs it externally.

[0021]

Here, in such a ball screw or a linear guide, when a circulating rolling element enters the load zone from a non-load zone, it collides with the raceway surface, and the free vibration of the raceway member on the side of the raceway surface due to the collision is excited Vibration is generated with the natural frequency of the raceway member as the frequency. When the acceleration pickup 10 is attached to such a raceway member, the acceleration pickup 10 detects the natural frequency of the raceway member due to the free vibration excited by the collision between the rolling body and the raceway surface with high sensitivity. In view of the above, in the present embodiment, the low-pass filter 13 filters the vibration frequency band that is equal to or higher than the natural frequency of the raceway member to which the acceleration pickup 10 is attached. That is, the low-pass filter 13 filters the frequency band of 8 times, preferably 6 times the calculated passing frequency of the rolling element. Here, when the object to be measured is a ball screw, the calculated pass frequency of the rolling element is calculated on the basis of the above formulas (1) to (3).

[0022]

Here, the frequency band of 8 times, preferably 6 times the calculated pass frequency of the rolling element is filtered by the low pass filter 13 for the following reason. FIG. 8 shows the result of the frequency analysis of the vibration acceleration of the ball screw. The result is obtained when an abnormality such as separation of the rolling elements in the ball screw occurs, and shows the vibration frequency analysis result before and after the occurrence of the abnormality. In the figure, the thick line is the result before the occurrence of the abnormality, and the thin line is the result after the occurrence of the abnormality. As shown in the figure, in the frequency band around 5 kHz both before and after the occurrence of the abnormality, the free vibration of the nut which is the raceway member to which the acceleration pickup is attached is excited by the collision between the transferred body and the raceway surface It can be seen that vibrations whose frequency is the natural frequency of the orbit member are generated. However, in the frequency band above 6 kHz, clear differences between before and after the abnormality are not recognized. On the other hand, in the frequency band below 3 kHz, the vibration of the frequency component in geometric proportional relation to the rotation speed clearly appears. For this reason, if filtering a frequency band of 5 kHz, preferably 6 kHz or more for the vibration acceleration signal detected by the acceleration pickup before and after the occurrence of the abnormality, a clear difference appears in the peak value or the rms value

of the vibration acceleration signal .

[0023]

At this time, with respect to the ball screw having such vibration characteristics, the calculated pass frequency of the rolling elements obtained from the above-mentioned formulas (1) to (3) is 500 Hz to 750 Hz. For this reason, by filtering the frequency band of 5 kHz, preferably 6 kHz or more, which is 8 times or more of the calculated pass frequency of 500 Hz to 750 Hz of this rolling element by the low pass filter 13, the peak value or the rms value of the vibration acceleration signal It becomes possible to obtain a clear difference. Alternatively, the low-pass filter may be set such that the largest one of the frequencies obtained by the expressions (1) to (3) is the reference (specific frequency) and is eight times or more the frequency.

[0024]

In addition, it is also possible to determine the frequency band to be filtered by the low-pass filter 13, taking into consideration the following individual events. FIG. 9 shows the peak-to-peak change rate of the vibration acceleration signal (output signal of the acceleration pickup) before and after the occurrence of the abnormality. In the figure, the vertical axis shows the ratio of the peak after abnormality occurrence to the peak before occurrence of abnormality (peak after abnormality / peak before occurrence of abnormality) as the peak-peak value change rate. In the case where no filter is applied (in the figure), it is not possible to obtain a clear difference between the peak-peak value change rate before and after the occurrence of the abnormality. That is, abnormality can not be detected. In addition, the peak-to-peak rate of change of the vibration acceleration signal obtained by filtering the frequency band of 6 kHz or more, which is a range in which a clear difference does not occur before and after the occurrence of abnormality by applying a low pass filter of 6 kHz Mark), it is difficult for a clear difference to appear between before and after the occurrence of an abnormality. This is because the frequency component of the natural vibration generated around 5 kHz can not be removed. On the other hand, when a low-pass filter of 3 kHz is applied, it is possible to sufficiently filter the natural vibration frequency band of 5 kHz or more, which is composed of the frequency component of the natural vibration etc., so that the difference clearly appears.

[0025]

Generally, it is important that the natural frequency of the raceway member excited by the collision between the rolling element and the raceway surface is in the range of 4 kHz to 100 kHz (see FIG. 10 below), furthermore, the geometrical proportion The frequency range in which the influence of the vibration of the related frequency component appears conspicuously is up to about 3 kHz. Thus, by setting the set value of the low-pass filter 13 to 3 kHz and measuring the vibration in the frequency range in which the influence of the geometrical vibration appears conspicuously by filtering the frequency component of the natural vibration The purpose can be achieved. When the frequency component of the natural vibration of the raceway member can be confirmed in advance, a low-pass filter can be set so that the vibration frequency band above the natural frequency can be sufficiently filtered.

[0026]

Also, the lowest frequency band (circle in FIG. 8, circled circle) may be filtered by the low-pass filter 13. That is, a frequency less than the calculated passing frequency of the rolling element is attenuated. For example, as a frequency less than the calculated pass frequency of the rolling element, there are a resonance frequency of the screw shaft of the ball screw, a vibration due to vibration from the outside of the rolling device, and the like. As a result, these vibrations can be blocked, and the peak value or the rms value of the vibration acceleration signal can be obtained as a clearer difference.

[0027]

As described above, in order to filter a plurality of frequency bands, it is effective to use filters having different attenuation frequencies and notch filters attenuating only specific frequencies. FIG. 10 shows the relationship between the frequency and the vibration intensity (db) with respect to the ball screw. FIG. 5 (a) shows the result of the ball screw of ϕ 50, and FIG. 6 (b) shows the result of the ball screw of ϕ 32. As described above, in the ball screw, the circulating rolling element collides with the raceway surface when entering the load zone from the non-load zone, and the free vibration of the element member on the raceway side due to the collision is excited and the element member Vibrations having the natural frequency of the frequency as a frequency are generated. Although the frequency band of the natural vibration caused by the collision between the rolling elements and the raceway surface is somewhat different depending on the size of the nut of the ball screw, as indicated by a circle in the drawing, in general, the frequency band of 4 kHz to 100 kHz .

[0028]

Also, the amplitude of the vibration generated by the collision between the rolling element and the raceway surface varies depending on the collision energy, so it can easily change or come back and forth depending on the difference in angle of entry of the individual rolling elements to the raceway surface In the case of direct acting elements and the like, it easily varies depending on the difference between forward (FIG. 11 (a)) and return (FIG. 11 (b)) and the like. Therefore, in a rolling element having a circulation part, there is a high possibility that a fault is erroneously detected by a conventional method. However, by applying the present invention, it is possible to detect an abnormality with high accuracy by filtering a frequency band having a specific frequency, for example, eight or more times the calculated pass frequency of the rolling element under such conditions It will be like.

[0029]

FIG. 12 shows an application example of the output signal of the acceleration pickup 10. Here, a configuration of an abnormality detection system 130 for detecting an abnormality of a rolling device (specifically, a track member, in this example, a ball screw 30 or a linear guide 90) is shown based on an output signal of the acceleration pickup 10. As shown in FIG. 12, the abnormality detection system 130 includes a storage unit 131 that stores output signals of the acceleration pickup 10 attached to the rolling device 120 (for example, the nut 32 and the slider 92), a storage unit 131 that stores the output signal of the acceleration pickup 10 A vibration acceleration display section 132 for externally outputting (displaying) the vibration acceleration based on the output signal, and an abnormality determination section 133 for making an abnormality determination based on the output signal stored in the storage section 131. Based on the signal stored in the storage unit 131, that is, the time series signal of the output signal (vibration acceleration signal) of the acceleration pickup 10, the abnormality determination unit 133 determines the peak value in the output signal or the rms value of the output signal And determines the abnormality of the rolling device 120 based on the peak value or the rms value. For example, an abnormality of the rolling device 120 is judged by comparison with a predetermined threshold value.

[0030]

Thus, it is possible to determine abnormality with high accuracy by using the output signal (vibration acceleration vibration) of the acceleration pickup 10. In addition, because abnormality

of the raceway member is judged based on the time series change of the output signal, an abnormality can be detected with high accuracy. In addition, it is possible to detect an abnormality only with the filter and the peak value display device (vibration acceleration display device) without using a frequency analyzing device and a plurality of computing devices, and therefore, while having a simple configuration, It can detect with accuracy.

[0031]

It should be noted that the first embodiment can be realized with the following configuration. That is, in the first embodiment, the expressions (1) to (3) are for obtaining the calculated pass frequency of the rolling elements of the ball screw. However, in the case of obtaining the calculated pass frequency of the rolling elements with respect to other rolling devices, for example linear guides, the above-mentioned formulas (1) to (3) are determined in accordance with various dimensions of the linear guides, Modify the equation. Thus, by calculating the calculated passing frequency of the rolling element for the linear guide and filtering the frequency band of 8 times, preferably 6 times the calculated pass frequency of the rolling element, the race member (guide rail or slider) Can be detected with high accuracy and an abnormality can be detected with high accuracy.

[0032]

Further, the low-pass filter 13 attenuates at least one of 4 times, 6 times, and 8 times the attenuation characteristic of 6 dB / oct more than the calculated passing frequency of the rolling element and the calculated pass frequency of the rolling element Can also be attenuated. As a result, it is possible to perform abnormality detection with high accuracy by appropriately selecting the frequency to be attenuated and the frequency to be subjected to abnormality detection. For example, when the frequency four times as high as the calculated pass frequency of the rolling element coincides with the disturbance frequency other than the objective, this is also attenuated and abnormality detection is performed at the frequency six times the calculated pass frequency of the rolling element, The detection accuracy can be improved. In the first embodiment, the output voltage of the acceleration sensor 11 is output to the low-pass filter 13 via the amplifier 12. On the other hand, even if the output voltage of the acceleration sensor 11 is directly output to the low-pass filter 13 and filtered, the abnormality can be detected with high accuracy as the same effect as described above.

[0033]

(Second Embodiment) Next, a second embodiment will be described. (Configuration) The second embodiment is also a vibration sensor to which the present invention is applied. FIG. 13 shows the configuration of the vibration sensor 20. As shown in FIG. 13, in the vibration sensor 20, an elastic body 25 serving as a mechanical filter means is disposed between the acceleration pickup 21 and the object to be measured (the track member of the rolling device) 200, and this elastic body 25 to fix the acceleration pickup 21 to the object 200 to be measured. The acceleration pickup 21 is a built-in amplifier type piezoelectric acceleration pickup. The acceleration pickup 21 is fixed to the workpiece 200 via an elastic body 25 by screwing.

[0034]

FIG. 14 shows the configuration of the acceleration pickup 21. As shown in FIG. 14, the acceleration pickup 21 includes a piezoelectric type acceleration sensor 22 that outputs a voltage corresponding to the acceleration at the time of vibration, and an amplifier 23 that amplifies the output voltage value of the acceleration sensor. For example, the acceleration sensor 22 is a so-called bimorph type piezoelectric acceleration sensor as in the first embodiment. FIG. 15 shows the characteristics of the acceleration pickup 21 (specifically, the acceleration sensor 22). As shown in FIG. 15, the frequency characteristic of the acceleration pickup 21 (specifically, the acceleration sensor 22) is substantially linear over 10 KHz. The amplifier 23 performs nonlinear output based on the output voltage value from the acceleration sensor 22 having such characteristics.

[0035]

The elastic body 25 is formed of rubber or an elastomer material or the like. As shown in FIG. 13, a hole 25 a for screw insertion is provided in the center of the elastic body 25, and the screw 26 is inserted through the hole 25 a so that the acceleration pickup 21 and the workpiece 200 are screwed. Then, the shape, physical property value, etc. of the elastic body 25 are determined so that vibration outside the object measurement frequency range can be cut off. That is, it is 8 times larger than the calculated frequency of the rolling elements obtained for a specific rolling device (for example, when the rolling device is a ball screw, see the above-mentioned formulas (1) to (3)), The shape of the elastic body 25, physical property values, etc. are determined so that the double frequency band can be mechanically filtered.

[0036]

With reference to FIGS. 16 to 18, a configuration example of a ball screw which is a rolling device having a vibration sensor 20 will be described. As shown in FIGS. 16 to 18, the ball screw 30 includes a screw shaft 31 as one race member, a nut 32 as another race member relatively moving in the axial direction as the screw shaft 31 rotates , A large number of balls 33 rollingly incorporated between the nut 32 and the screw shaft 31, and a side cap 34 as a ball circulating member for circulating these balls 33. The screw shaft 31 has a circular cross section orthogonal to the axial direction, and a helical ball screw groove 41 which is a raceway groove is formed on the outer peripheral surface thereof. The ball screw groove 41 faces a spiral ball screw groove 42 which is a raceway groove formed on the inner peripheral surface of the nut 32. When one of the screw shaft 31 or the nut 32 rotates around the axis, So that the ball 33 rolls on the ball loaded rolling path 43 serving as a rolling path formed between the ball screw grooves 41 and 42.

[0037]

The nut 32 has a side cap attachment surface 51 on its outer circumferential surface, and ball circulation holes 52, 52 for circulating the ball 33 are formed on the side cap attachment surface 51. The side cap 34 is formed, for example, by injection molding a molding material such as resin or metal into a predetermined shape. The side cap 34 has a pair of columnar ball scooping portions 34 a, 34 b fitted in the ball circulation holes 52, 52 and balls communicating with the ball return guide paths 53, 53 formed in these columnar ball scooping portions 34 a, 34 b And a plate-shaped side cap body portion 34 c having a return passage 54 therein. Here, as a structure including the ball loaded rolling path 43, the ball returning guide path 53, and the ball returning path 54, a rolling element circulating path for circulating the balls 33 is configured.

[0038]

The cross-section of the ball-scooping parts 34a, 34b is formed in a circular shape, so that the cross-section of the ball circulation hole 52 into which the ball scooping parts 34a, 34b are fitted is also circular. As shown in FIG. 18, the balls 33 rolling on the ball loaded rolling path 43 are tang portions of the ball scooping portion 34 a or 34 b, respectively, and the ball scooping portions 34 a and 34 b have tongue portions So that it is picked up in the direction of the lead angle of the ball screw grooves 41 and 42 and introduced into the ball return passage 54.

[0039]

As shown in FIG. 5, the vibration sensor 20 is attached to the side cap 34 which is a member on the nut 32 side of the ball screw 30 configured as described above. At this time, the vibration sensor 20 is mounted so that the elastic body 25 is interposed between the acceleration pickup 21 and the nut 32. The vibration sensor 20 externally outputs a detection signal (voltage value) by a sensor cable 27.

[0040]

(Operation, Operation and Effect) Operation, operation and effect are as follows. The vibration sensor 20 (specifically, the acceleration pickup 21) detects the vibration of the ball screw 30 when the nut 32 and the screw shaft 31 move relative to each other. Then, the vibration sensor 20 externally outputs the detection signal by the sensor cable 27. At this time, since the elastic body 25 exists between the acceleration pickup 21 and the workpiece 200, the vibration signal of the workpiece 200 is transmitted to the acceleration pickup 21 via the elastic body 25. As a result, the vibration signal outside the object measurement frequency range is blocked at the stage before the elastic body 25 acts as a filter and is input to the acceleration pickup 21. Therefore, the acceleration pickup 21 can measure vibration at a high level over a wide frequency range. Further, by using the elastic member 25 as the filter means, the filter means can be constructed easily.

[0041]

Here, if a charge output type acceleration pickup is used for detecting the vibration of a linear motion element such as a ball screw, a linear guide, a rack pinion or the like which repeats the reciprocating motion, the problem that the noise accompanying the bending of the cable gets on the vibration detection signal there were. On the other hand, in the piezoelectric type acceleration pickup with built-in amplifier, noise accompanying bending of the cable rarely rides on the vibration detection signal. However, the built-in amplifier type piezoelectric acceleration pickup has a problem that the dynamic range is narrow and overloading is easy as compared with the charge output type acceleration pickup. That is, in the built-in amplifier type pickup, since vibration is directly input without filtering, when the vibration is large, the built-in amplifier overloads (the sensitivity of the vibration with a higher frequency is higher than the vibration with the low frequency growing). As a result, the use of the built-in pickup of the amplifier has been limited to the vibration measurement within the vibration level range where the built-in

amplifier does not overload. Therefore, in the vibration of a linear motion element such as a ball screw, a linear guide or a rack pinion, the high frequency component becomes strong due to the vibration etc. of the ball running the grinding trace, so in the detection of such vibration, There arises a problem that the formula acceleration pickup tends to be overloaded.

[0042]

In the charge output type acceleration pickup using the external amplifier, since it is possible to narrow down the target measurement frequency range (the frequency range to be monitored) by applying an external filter, it is also possible to input vibration signals at a high level over a wide frequency range , It is possible to identify and measure the vibration of the target measurement frequency range. However, in the charge output type acceleration pickup, as described above, in the detection of the vibration of a linear motion element such as a ball screw, a linear guide, a rack pinion and the like which repeats reciprocating motion, noise accompanying the bending of the cable will ride on the signal Can not be resolved.

[0043]

With respect to the various problems as described above, by cutting off the vibration composed of the high frequency component outside the target measurement frequency range at the stage prior to being input to the acceleration pickup 21, the vibration was buried in the high frequency component outside the target measurement frequency range It becomes possible to detect the vibration of the object to be monitored (including the vibration of the high frequency component). Moreover, by blocking the vibration composed of the high frequency component outside the object measurement frequency range at a stage before being input to the acceleration pickup 21, it is possible to prevent the overload of the acceleration pickup 21 from occurring and reliably detect the vibration of the monitoring target become able to. Since the acceleration pickup 21 is an amplifier built-in type piezoelectric acceleration pickup, the influence of noise due to cable bending can be reduced.

[0044]

It is also possible to determine the frequency range to be filtered by considering the following individual events. For example, the maximum speed of the linear motion rolling element reaches DN = 160,000 mm / min in the case of a ball screw, and the relative speed between the rolling

element and the raceway groove at this time is about 1.5 m / s. In addition, the raceway surface has grinding marks by grinding abrasive grains due to the fact that superfinishing is not carried out, and the pitch of the projections and depressions in the rolling direction of the rolling element due to the superfinishing is dependent on the processing conditions, but it is about 150 μm Or less, mainly about 50 μm. From this, when the rolling element rolls at the highest speed in the raceway groove, the vibration frequency due to the roughness in the track groove is 10 KHz (= 1.5 · E 6/150) even though it is estimated small, mainly , 30 KHz (= 1.5 · E 6/50). By lowering the sensitivity to vibration of such frequency and monitoring with the acceleration pickup 21, it is possible to detect lower frequency vibration occurring due to detachment of the track surface or jamming.

[0045]

In view of the above, the shape of the elastic body 25, the physical property value and the like are set such that the vibration of the high frequency component of 30 kHz or more due to the collision of the ball and the rolling path (raceway groove) . By doing so, the sensitivity to vibration due to the collision between the ball and the rolling path (raceway groove) is reduced, the vibration of lower frequency occurring due to the peeling of the raceway surface and jamming is detected by the acceleration pickup 21 it can.

[0046]

The reason for not performing the superfinishing of the raceway surface in the linear motion rolling element is as follows, for example. In direct acting rolling elements (hereinafter referred to as bearings), generally super finishing of the raceway surface is carried out, but unlike bearings, the raceway grooves are endless straight lines or spiral shapes, so that their length Since it is inevitable to produce a large variety of small quantities and it is difficult in terms of cost and its use speed is naturally restricted due to the fact that the raceway groove is endless, it is impossible to demonstrate the performance suitable for superfinishing In addition, the effect of superfinishing is masked by the vibration when the rolling element enters and exits the circulation path and the raceway groove.

[0047]

In addition, in particular, when the ball screw groove of the screw shaft or the nut is formed in a

gothic arch shape, super finishing of swinging the grinding wheel left and right can not be performed, so that when the rolling element rolls through the ball screw groove, Vibration is inevitable. From this, it is possible to detect vibration of a lower frequency occurring due to peeling of the raceway surface of the ball screw groove or jamming, by lowering the sensitivity to vibration of the frequency and monitoring with the acceleration pickup 21.

[0048]

Even in the case where the screw shaft, the nut (specifically, the ball screw groove thereof), or the rolling element is made of a metal (eg, steel) or ceramic formed by grinding finish, the rolling element also has a ball screw groove It is inevitable that vibrations will be generated by the unevenness when rolling. From this, it is possible to detect vibration of a lower frequency occurring due to peeling of the raceway surface of the ball screw groove or jamming, by lowering the sensitivity to vibration of the frequency and monitoring with the acceleration pickup 21.

[0049]

Also, when superfinishing is performed, although the level decreases, vibration of high frequency component of approximately the same degree can be detected in the linear motion rolling element. This vibration is considered to be the vibration of the high frequency component generated when the rolling element enters and exits the circulation path and the raceway groove. Even in such a case, application of the present invention reduces the sensitivity to vibration of such frequency and monitors with the acceleration pickup 21, whereby it is possible to detect the frequency lower than the frequency generated due to the detachment of the track surface or the clogging Can be detected.

[0050]

It should be noted that the second embodiment can be realized by the following configuration. That is, in the second embodiment, the acceleration pickup 21 and the elastic body 25 are fixed to the workpiece 200 by screws. In contrast, it can be fixed by other fixing means such as wax, adhesive, double-sided tape or magnet. For example, one or both of the acceleration pickup 21 and the elastic body 25, the elastic body 25 and the workpiece 200 are fixed with a wax, an adhesive, a double-faced tape, a magnet, or the like.

[0051]

(Third Embodiment) Next, a third embodiment will be described. The third embodiment is also a vibration sensor, and FIG. 19 shows the configuration of the vibration sensor 60. As shown in FIG. 19, the vibration sensor 60 in the third embodiment includes the mass member 61 in the acceleration pickup 21. The mass member 61 is determined so that the vibration sensor 60 (in particular, the acceleration pickup 21) has a predetermined natural frequency. In this manner, by adjusting the natural frequency of the vibration sensor 60 (in particular, the acceleration pickup 21) by the mass member 61, the range of the high frequency vibration component to be blocked by the vibration sensor 60 can be adjusted.

[0052]

Here, the following equation (4) shows the natural frequency f 0 of the first-order spring mass system. $f0 = 1 / (2\pi) \cdot \sqrt{(k / M)}$ (4) where k is the spring constant and M is the mass. When this equation (4) is applied to the configuration of the vibration sensor 60, k is the spring constant of the elastic body 25, and M is the mass of the acceleration pickup 21 including the mass member 61. Therefore, as can be understood from the expression (4), by adding the mass member 61 to the acceleration pickup 21, it is possible to change the natural frequency f 0 of the acceleration pickup 21 including the mass member 61. As a result, It is possible to adjust the range of the high frequency vibration component to be blocked by the vibration sensor 60 (the frequency band of 8 times, preferably 6 times the calculated passing frequency of the rolling element).

[0053]

In the third embodiment, the mass member 61 is added to the acceleration pickup 21 to change the natural frequency, but it is also possible to change the natural frequency by another method. That is, by changing the fixing method of the acceleration pickup 21 and the elastic body 25 or the fixing method of the acceleration pickup 21 and the object 200 to be measured appropriately, it is possible to change the natural frequency. Further, by changing the weight of the acceleration pickup 21 itself, such as the thickness of the elastic body 25 and the material (physical property value), the natural frequency can be changed.

[0054]

(Fourth Embodiment) Next, a fourth embodiment will be described. The fourth embodiment is also a vibration sensor, and FIG. 20 shows the configuration of the vibration sensor 70. As shown in FIG. 20, in the vibration sensor 70 according to the fourth embodiment, the acceleration pickup 21 and the elastic body 25, and the elastic body 25 and the object to be measured 200 are individually fixed by screws 71, 72. For example, by adopting such a configuration, the natural frequency of the vibration sensor 70 can be changed, and the range of the high frequency vibration component to be blocked by the vibration sensor 70 can be adjusted.

[0055]

Fifth Embodiment Next, a fifth embodiment will be described. The fifth embodiment is also a vibration sensor, and FIG. 21 shows the configuration of the vibration sensor 80. As shown in FIG. 21, the vibration sensor 80 fixes the acceleration pickup 21 and the elastic body 25, and the elastic body 25 and the object to be measured 200 individually. In the fifth embodiment, unlike the case of the fourth embodiment, the elastic member 25 is fixed to the workpiece 200 by using the attachment member 82 that surrounds the outer circumferential portion of the elastic body 25. For example, with such a configuration, the natural frequency of the vibration sensor 80 can be changed, and the range of the high frequency vibration component to be blocked by the vibration sensor 80 can be adjusted.

[0056]

1 is a block diagram showing a configuration of a vibration sensor (acceleration pickup) provided in a rolling device according to a first embodiment of the present invention. FIG. 7 is a characteristic diagram showing attenuation characteristics of a low-pass filter of an acceleration pickup. FIG. FIG. 4 is a circuit diagram showing an example of a configuration of a low-pass filter. FIG. 7 is a diagram showing an example of attaching an acceleration pickup to a ball screw. FIG. 7 is a view showing another example of attachment of an acceleration pickup to a ball screw. FIG. 4 is a diagram showing an example of attaching an acceleration pickup to a linear guide. FIG. 6 is a view showing another example of attachment of an acceleration pickup to a linear guide. FIG. 7 is a characteristic diagram showing a result of frequency analysis of a vibration acceleration of a ball screw. 7 is a characteristic diagram showing a peak-to-peak value change rate of a vibration acceleration signal (output signal of an acceleration pickup) before and after occurrence of an abnormality. FIG. FIG. 7 is a characteristic diagram showing the relationship between frequency

and vibration strength (db) with respect to a ball screw. 6 is a characteristic diagram used for explaining a difference in vibration during reciprocation in a linear motion element or the like. FIG. FIG. 2 is a block diagram showing a configuration of an abnormality detection system including a speed pickup. FIG. 7 is a diagram showing a configuration of a vibration sensor included in a rolling device according to a second embodiment of the present invention. FIG. 7 is a block diagram showing a configuration of a vibration sensor (acceleration pickup) according to a second embodiment. 7 is a characteristic diagram showing characteristics of an acceleration pickup according to a second embodiment. FIG. FIG. 4 is a plan view showing a configuration of a ball screw provided with a vibration sensor. FIG. 3 is an axial sectional view showing a configuration of a ball screw provided with a vibration sensor. 4 is a radial sectional view showing a configuration of a ball screw provided with a vibration sensor. FIG. FIG. 7 is a diagram showing a configuration of a vibration sensor included in the rolling device of the third embodiment. FIG. 7 is a diagram showing a configuration of a vibration sensor included in the rolling device of the fourth embodiment. FIG. 11 is a diagram showing a configuration of a vibration sensor included in the rolling device of the fifth embodiment.

Explanation of sign

[0057]

10 acceleration pickup (vibration sensor), 11 acceleration sensor, 12 amplifier, 13 low-pass filter, 20 vibration sensor, 21 acceleration pickup, 25 elastic body

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	William LeFebvre
Art Unit	3617
Examiner Name	Jason C. Smith
Attorney Docket Number	037659.00060 (P37056A US)

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20040201464	A1	2004-10-14	Oonishi	Japanese Version of JP2004294419 cited in JPO Office Action listed below.

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2009210301	JP	A	2009-09-17	NSK LTD	Machine Language Translation included.	
	2	2004294419	JP	A1	2004-10-21	Denso Corp	See US 20040201464 cited above.	

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	William LeFebvre
	Art Unit	3617
	Examiner Name	Jason C. Smith
	Attorney Docket Number	037659.00060 (P37056A US)

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	Office Action Dated July 3, 2018 issued by Japanese Patent Office in related Japanese Patent application 2016-542732.	

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	William LeFebvre
	Art Unit	3617
	Examiner Name	Jason C. Smith
	Attorney Docket Number	037659.00060 (P37056A US)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2018-08-08
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

29880 7590 09/06/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER
SMITH, JASON C

ART UNIT	PAPER NUMBER
3617	

DATE MAILED: 09/06/2018

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

TITLE OF INVENTION: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	12/06/2018

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

29880 7590 09/06/2018
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

TITLE OF INVENTION: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	12/06/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
SMITH, JASON C	3617	246-16900R

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

29880 7590 09/06/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
SMITH, JASON C	

ART UNIT	PAPER NUMBER
3617	

DATE MAILED: 09/06/2018

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/108,065	Applicant(s) LeFebvre et al.	
	Examiner JASON C SMITH	Art Unit 3617	AIA Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 08/08/2018.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 08/08/2018.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/Jason C Smith/
Primary Examiner, Art Unit 3617

Continuation of 3. The allowed claim(s) is/are: 1-2,4-5,8-9,11-21,27-28,31,35-36,39,42,45,49,51-52,60 and 66-71

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

CPC								
Symbol							**Type**	**Version**
B61L	/	27	/	0094			F	2013-01-01
B61L	/	15	/	0027			I	2013-01-01
B61L	/	15	/	0081			I	2013-01-01
B61K	/	9	/	00			I	2013-01-01
B61K	/	9	/	04			I	2013-01-01
B61L	/	25	/	021			I	2013-01-01
B61L	/	25	/	025			I	2013-01-01
B61L	/	27	/	0077			I	2013-01-01
G01M	/	17	/	10			I	2013-01-01
B61L	/	15	/	0036			A	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	35	
/Jason C Smith/ Primary Examiner, Art Unit 3617	13 August 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20180813

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

INTERNATIONAL CLASSIFICATION					
CLAIMED					
B61L	/	27	/	00	
NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 35	
/Jason C Smith/ Primary Examiner, Art Unit 3617 (Primary Examiner) 13 August 2018 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office Part of Paper No.: 20180813

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	18	10	13	19	5	28		37		46		55		64
2	2	20	11	14	20		29		38		47	33	56		65
	3	19	12	15	21		30		39		48		57	23	66
3	4	21	13		22	22	31		40	17	49		58	24	67
6	5	8	14		23		32		41		50		59	25	68
	6	9	15		24		33	32	42		51	34	60	26	69
	7	10	16		25		34		43		52	35	61	27	70
7	8	11	17		26	29	35		44		53		62	28	71
4	9	12	18	16	27	30	36	31	45		54		63		

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	35	
/Jason C Smith/ Primary Examiner, Art Unit 3617	13 August 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office Part of Paper No.: 20180813

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	Art Unit
	JASON C SMITH	3617

CPC - Searched*		
Symbol	Date	Examiner
B60T 17/22	10/27/2017	jcs
B61L 15/00, 0018, 0027, 0054, 0072, 0081	10/27/2017	jcs
G01K 7/02	10/27/2017	kcs
G06F 19/00	10/27/2017	jcs
G08B 21/18	10/27/2017	jcs

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
east text search	10/27/2017	jcs
searches updated	04/27/2018	jcs
searches updated	08/13/2018	jcs

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
B61L	15/00, 0018, 0027, 0054, 0072, 0081	08/13/2018	jcs

/Jason C Smith/ Primary Examiner, Art Unit 3617	

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	William LeFebvre
Art Unit	3617
Examiner Name	Jason C. Smith
Attorney Docket Number	037659.00060 (P37056A US)

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20040201464	A1	2004-10-14	Oonishi	Japanese Version of JP2004294419 cited in JPO Office Action listed below.

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2009210301	JP	A	2009-09-17	NSK LTD	Machine Language Translation included.	
	2	2004294419	JP	A1	2004-10-21	Denso Corp	See US 20040201464 cited above.	

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	William LeFebvre
Art Unit	3617
Examiner Name	Jason C. Smith
Attorney Docket Number	037659.00060 (P37056A US)

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	Office Action Dated July 3, 2018 issued by Japanese Patent Office in related Japanese Patent application 2016-542732.	

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature	/Jason C Smith/	Date Considered	08/13/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	William LeFebvre
Art Unit	3617
Examiner Name	Jason C. Smith
Attorney Docket Number	037659.00060 (P37056A US)

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2018-08-08
Name/Print	Gary A. Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	1	"15108065"	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:13
S2	28	("20050259619" | "20060264221" | "20070241610" | "20080195265" | "20090001226" | "20090173840" | "20100200307" | "20110270475" | "20110282540" | "3718040" | "5446451" | "5603556" | "5682139" | "5691980" | "6175784" | "6184798" | "6301531" | "6339397" | "6668216" | "7336156" | "7688218" | "7698962" | "8244411" | "8370006" | "8672273" | "8751290" | "9365223" | "9663092").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:14
S3	1769	b60t17/22.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S4	36	b61l15/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S5	584	g01k7/02.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S6	1843	g06f19/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:18
S7	2244	g08b21/18	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S8	116	246/129.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S9	3732	340/438.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S10	1338	340/870.16.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S11	737	340/870.17.ccls.	US-PGPUB;	OR	OFF	2017/10/27 16:19

			USPAT; USOCR			
S12	470	374/152.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S13	1525	701/19.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S14	543	701/20.ccls.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S15	725	b61l15/0027.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:19
S16	127	b61l15/0054.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S17	342	b61l15/0072.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S18	435	b61l15/0081.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S19	59	b61l15/0018.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S20	388	martin adj andrew.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S21	42	cooper adj francis.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:20
S22	1	adamec adj rachel.in.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S23	243	b61l27/0094.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S24	83	b61k9/00.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S25	295	b61k9/04.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21

S26	608	b61l25/021.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21
S27	869	b61l25/025.cpc.	US-PGPUB; USPAT; USOCR	OR	OFF	2017/10/27 16:21

8/13/2018 2:58:17 PM
C:\Users\jsmith8\Documents\EAST\Workspaces\15108065.wsp

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

29880 7590 09/19/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
SMITH, JASON C	

ART UNIT	PAPER NUMBER
3617	

NOTIFICATION DATE	DELIVERY MODE
09/19/2018	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocket@foxrothschild.com

Corrected ***Notice of Allowability***	**Application No.** 15/108,065	**Applicant(s)** LeFebvre et al.	
	Examiner JASON C SMITH	**Art Unit** 3617	**AIA Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 08/08/2018.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/Jason C Smith/
Primary Examiner, Art Unit 3617

Continuation of 3. The allowed claim(s) is/are: 1-2,4-5,8-9,11-21,27-28,31,35-36,39,42,49,52,56,60-61 and 66-71

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: **W. LeFebvre et al.**	Group Art Unit: **3617**
Application No.: **15/108,065**	Examiner: **Jason C. Smith**
Filing Date: **June 24, 2016**	Attorney Docket: **037659.00060**
For: **System and Method for Detecting Operational Anomalies in Train Consists and Railcars**	Customer No.: **29880**
	Confirmation No.: **1019**

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REQUEST FOR 2ND CORRECTED NOTICE OF ALLOWABILITY

Sir:

This is in response to the Corrected Notice of Allowability dated September 19, 2018.

On page 3 of the Corrected Notice, the following allowed claims were listed: 1-2, 4-5, 8-9, 11-21, 27-28, 31, 35-36, 39, 42, 49, 52, 56, 60-61 and 66-71. Claims 10 and 45 are missing from this list of allowed claims.

The correct list of allowed claims should read as follows: 1-2, 4-5, 8-21, 27-28, 31, 35-36, 39, 42, 45, 49, 52, 56, 60-61 and 66-71.`

A corrected Notice of Allowability is requested.

Respectfully submitted,

Date: September 26, 2018

/gah/
Gary A. Hecht
Reg. No. 36,826
Gregory V. Madden
Registration No. 64,528
Fox Rothschild LLP
2000 Market St.; 20th Floor
Philadelphia, PA 19103
Telephone: 215-299-2000
Facsimile: 610-299-2150

Electronic Acknowledgement Receipt

EFS ID:	33835786
Application Number:	15108065
International Application Number:	
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht/Natalie Ward
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	26-SEP-2018
Filing Date:	24-JUN-2016
Time Stamp:	15:16:41
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Miscellaneous Incoming Letter	Request_for_correction_of_NOA_Second_Correction.pdf	8801 2f30f8ca7c64e313946488ea2f6aa1118ebfcfc7	no	1

Warnings:

Information:	
Total Files Size (in bytes):	8801

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

29880 7590 10/03/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
SMITH, JASON C	

ART UNIT	PAPER NUMBER
3617	

NOTIFICATION DATE	DELIVERY MODE
10/03/2018	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocket@foxrothschild.com

Corrected ***Notice of Allowability***	**Application No.** 15/108,065	**Applicant(s)** LeFebvre et al.	
	Examiner JASON C SMITH	**Art Unit** 3617	**AIA Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☐ This communication is responsive to _____.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/Jason C Smith/
Primary Examiner, Art Unit 3617

Continuation of 3. The allowed claim(s) is/are: 1-2,4-5,8-21,27-28,31,35-36,39,42,45,49,52,56,60-61 and 66-71

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. Lefebvre
Art Unit	3617
Examiner Name	J. Smith
Attorney Docket Number	P37056A US

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. Lefebvre
	Art Unit	3617
	Examiner Name	J. Smith
	Attorney Docket Number	P37056A US

	1	"Mechanical Engineering Test Technologies", HAN Jianhai, et al., Beijing China: Tsinghua University Press, pages 77-80, May 2010. The relevance of this reference is discussed on page 6 of the English Translation of the CPO Office Action listed below.	X
	2	Office Action Dated August 31, 2018 issued by the CPO in related Chinese patent application 201480076070.3. References D1 and D2 as cited in the Office Action, or US equivalents thereof, were previously made of record in the present application. D1 (CN101346268A) is a Chinese equivalent of US Patent 7688218.	☒

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15108065
	Filing Date	2016-06-24
	First Named Inventor	W. Lefebvre
	Art Unit	3617
	Examiner Name	J. Smith
	Attorney Docket Number	P37056A US

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☒ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

☒ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2018-10-08
Name/Print	Gary Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:	15108065
Filing Date:	24-Jun-2016
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Filer:	Gary A. Hecht
Attorney Docket Number:	P37056A US (37659.00060)

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
		Total in USD ($)		**240**

Electronic Acknowledgement Receipt

EFS ID:	33945789
Application Number:	15108065
International Application Number:	
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht
Filer Authorized By:	
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	08-OCT-2018
Filing Date:	24-JUN-2016
Time Stamp:	17:17:11
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$240
RAM confirmation Number	100918INTEFSW17175700
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	IDS_CPO.pdf	1055898 4ca4ca29395d93d324b3a75893c7583dfcbe938c	no	4
Warnings:					
Information:					
A U.S. Patent Number Citation or a U.S. Publication Number Citation is required in the Information Disclosure Statement (IDS) form for autoloading of data into USPTO systems. You may remove the form to add the required data in order to correct the Informational Message if you are citing U.S. References. If you chose not to include U.S. References, the image of the form will be processed and be made available within the Image File Wrapper (IFW) system. However, no data will be extracted from this form. Any additional data such as Foreign Patent Documents or Non Patent Literature will be manually reviewed and keyed into USPTO systems.					
2	Non Patent Literature	Chinese_Office_Action_and_Translation.pdf	1260983 1c488cb639f4f0906f178f4f86f5484f995ff500	no	27
Warnings:					
Information:					
3	Non Patent Literature	Mechanical_Engin_Test_T_with_English_Translation___.pdf	632582 d8b511845ea75f5418614ae48dc85f1cef9ab11d	no	18
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	30968 449e3caa984cbe82069d14251da9ecc0a076e982	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	2980431		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

29880 7590 10/17/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
SMITH, JASON C	

ART UNIT	PAPER NUMBER
3617	

NOTIFICATION DATE	DELIVERY MODE
10/17/2018	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ipdocket@foxrothschild.com

UNITED STATES DEPARTMENT OF COMMERCE
U.S. Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450

APPLICATION NO./ CONTROL NO.	FILING DATE	FIRST NAMED INVENTOR/ PATENT IN REEXAMINATION	ATTORNEY DOCKET NO.
15/108,065	06/24/2016	LeFebvre et al.	P37056A US (37659

FOX ROTHSCHILD LLP PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE BLDG. #3
LAWRENCEVILLE, NJ 08648

EXAMINER	
JASON C SMITH	
ART UNIT	PAPER
3617	20181013

DATE MAILED: _____

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner for Patents

The IDS dated 10/08/2018 has been considered.

/Jason C Smith/
Primary Examiner, Art Unit 3617

PTO-90C (Rev.04-03)

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. Lefebvre
Art Unit	3617
Examiner Name	J. Smith
Attorney Docket Number	P37056A US

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. Lefebvre
Art Unit	3617
Examiner Name	J. Smith
Attorney Docket Number	P37056A US

	1	"Mechanical Engineering Test Technologies", HAN Jianhai, et al., Beijing China: Tsinghua University Press, pages 77-80, May 2010. The relevance of this reference is discussed on page 6 of the English Translation of the CPO Office Action listed below.	☒
	2	Office Action Dated August 31, 2018 issued by the CPO in related Chinese patent application 201480076070.3. References D1 and D2 as cited in the Office Action, or US equivalents thereof, were previously made of record in the present application. D1 (CN101346268A) is a Chinese equivalent of US Patent 7688218.	☒

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature	/Jason C Smith/	Date Considered	10/13/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15108065
Filing Date	2016-06-24
First Named Inventor	W. Lefebvre
Art Unit	3617
Examiner Name	J. Smith
Attorney Docket Number	P37056A US

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

X That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

X The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/gah/	Date (YYYY-MM-DD)	2018-10-08
Name/Print	Gary Hecht	Registration Number	36826

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /JCS/

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

29880 7590 09/06/2018
FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	06/24/2016	William LeFebvre	P37056A US (37659.00060)	1019

TITLE OF INVENTION: SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	12/06/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
SMITH, JASON C	3617	246-16900R

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Fox Rothschild LLP
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: AMSTED RAIL COMPANY, INC.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): CHICAGO, IL 60606

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number 50-1943 (enclose an extra copy of this form).

XXXXXXXXXXXXXXX

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /gah/ Date October 19, 2018

Typed or printed name Gary A. Hecht Registration No. 36826

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	15108065
Filing Date:	24-Jun-2016
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Filer:	Gary A. Hecht/Natalie Ward
Attorney Docket Number:	P37056A US (37659.00060)

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1000**

Electronic Acknowledgement Receipt

EFS ID:	34061501
Application Number:	15108065
International Application Number:	
Confirmation Number:	1019
Title of Invention:	SYSTEM AND METHOD FOR DETECTING OPERATIONAL ANOMALIES IN TRAIN CONSISTS AND RAILCARS
First Named Inventor/Applicant Name:	William LeFebvre
Customer Number:	29880
Filer:	Gary A. Hecht/Natalie Ward
Filer Authorized By:	Gary A. Hecht
Attorney Docket Number:	P37056A US (37659.00060)
Receipt Date:	19-OCT-2018
Filing Date:	24-JUN-2016
Time Stamp:	14:13:23
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	102218INTEFSW14140700
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Fee_Transmittal.pdf	75774 62f552acddfa560f02dd09be5434701c4f16c81b	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30740 69ba97795ed8aab3d002d9c53dd02f7e0188928d	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	106514		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

CPC								
Symbol							**Type**	**Version**
B61L	/	27	/	0094			F	2013-01-01
B61L	/	15	/	0027			I	2013-01-01
B61L	/	15	/	0081			I	2013-01-01
B61K	/	9	/	00			I	2013-01-01
B61K	/	9	/	04			I	2013-01-01
B61L	/	25	/	021			I	2013-01-01
B61L	/	25	/	025			I	2013-01-01
B61L	/	27	/	0077			I	2013-01-01
G01M	/	17	/	10			I	2013-01-01
B61L	/	15	/	0036			A	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	37	
/Jason C Smith/ Primary Examiner, Art Unit 3617	30 October 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20181030

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

INTERNATIONAL CLASSIFICATION					
CLAIMED					
B61L	/	27	/	00	
NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	37	
/Jason C Smith/ Primary Examiner, Art Unit 3617	30 October 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20181030

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/108,065	LeFebvre et al.
	Examiner	**Art Unit**
	JASON C SMITH	3617

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	19	10	11	19	7	28		37		46		55		64
2	2	21	11	12	20		29		38		47	35	56		65
	3	20	12	13	21		30	32	39		48		57	24	66
6	4	22	13		22	23	31		40	4	49		58	25	67
9	5	14	14		23		32		41		50		59	26	68
	6	15	15		24		33	33	42		51	36	60	27	69
	7	16	16		25		34		43	3	52	37	61	28	70
10	8	17	17		26	30	35		44		53		62	29	71
8	9	18	18	5	27	31	36	34	45		54		63		

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	37	
/Jason C Smith/ Primary Examiner, Art Unit 3617	30 October 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20181030

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/108,065	11/27/2018	10137915	P37056A US (37659.00060)	1019

29880 7590 11/07/2018

FOX ROTHSCHILD LLP
PRINCETON PIKE CORPORATE CENTER
997 LENOX DRIVE
BLDG. #3
LAWRENCEVILLE, NJ 08648

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

William LeFebvre, West Chester, PA;
AMSTED RAIL COMPANY, INC., Chicago, IL;
Andrew Martin, West Chester, PA;
Francis James COOPER, Downingtown, PA;
Rachel W. ADAMEC, Norristown, PA;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.