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(54) **FUNCTIONAL COMPONENT, STRUCTURE FOR ATTACHING FUNCTIONAL COMPONENT TO TIRE, AND TIRE**

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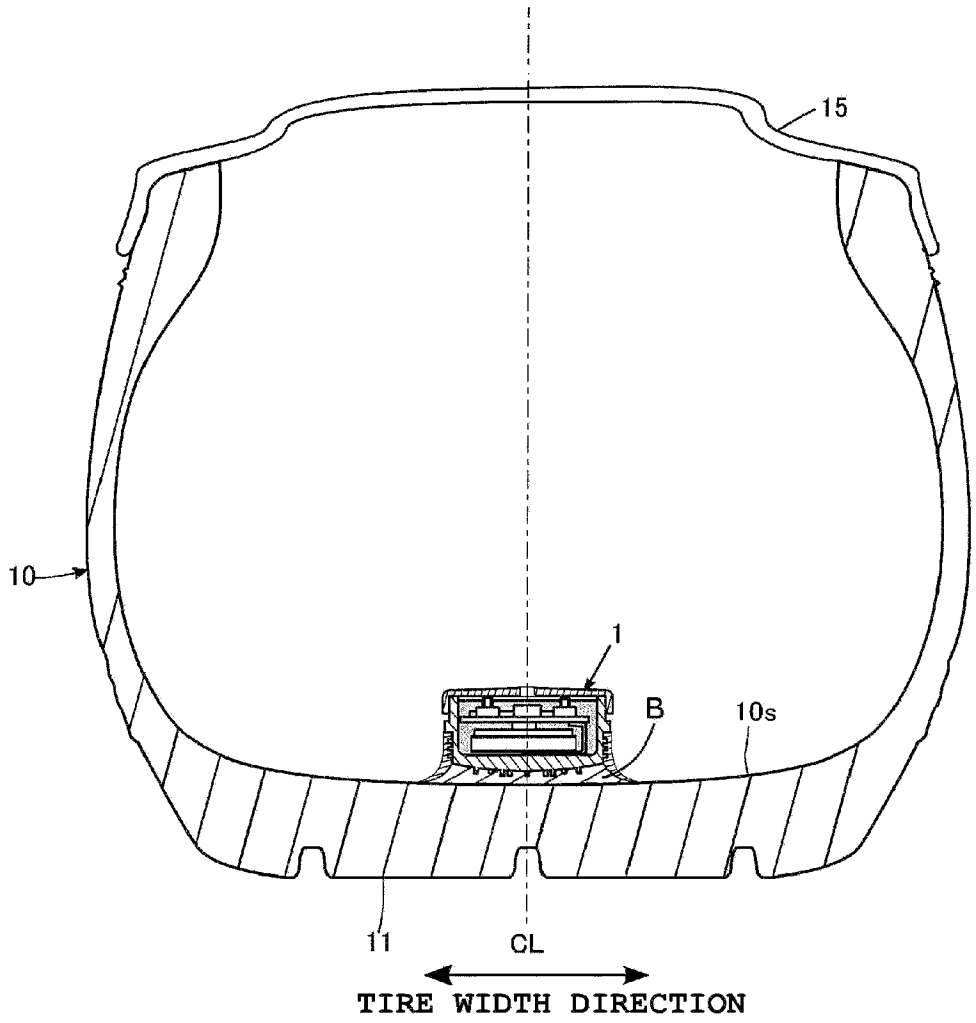
CPC ***B60C 23/0493*** (2013.01); *B60C 2019/004* (2013.01); ***B29D 30/0061*** (2013.01); ***B60C 23/064*** (2013.01)

(57) **ABSTRACT**

A functional component in which an electronic component capable of acquiring information inside a tire is housed and which is attachable to an inner peripheral surface of the tire, the functional component including a housing having a housing part for the electronic component and a bottom surface facing the inner peripheral surface of the tire, and a tubular part extending from a peripheral edge of the bottom surface toward the inner peripheral surface.



Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 001

FIG.1A

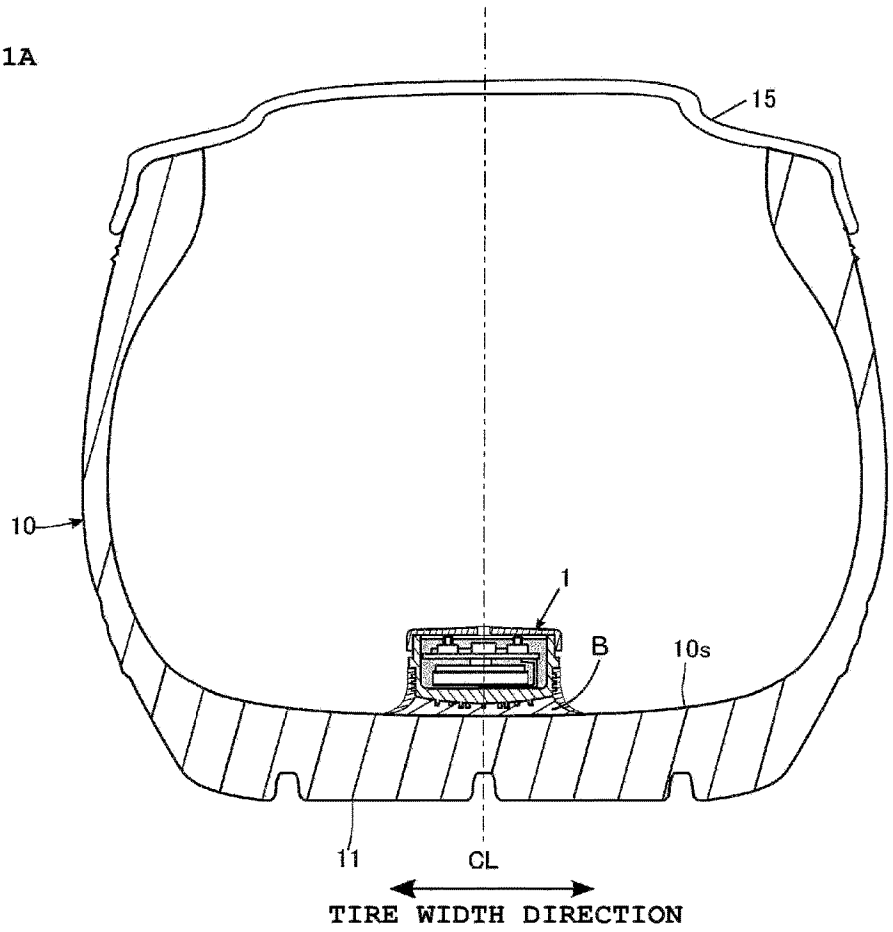
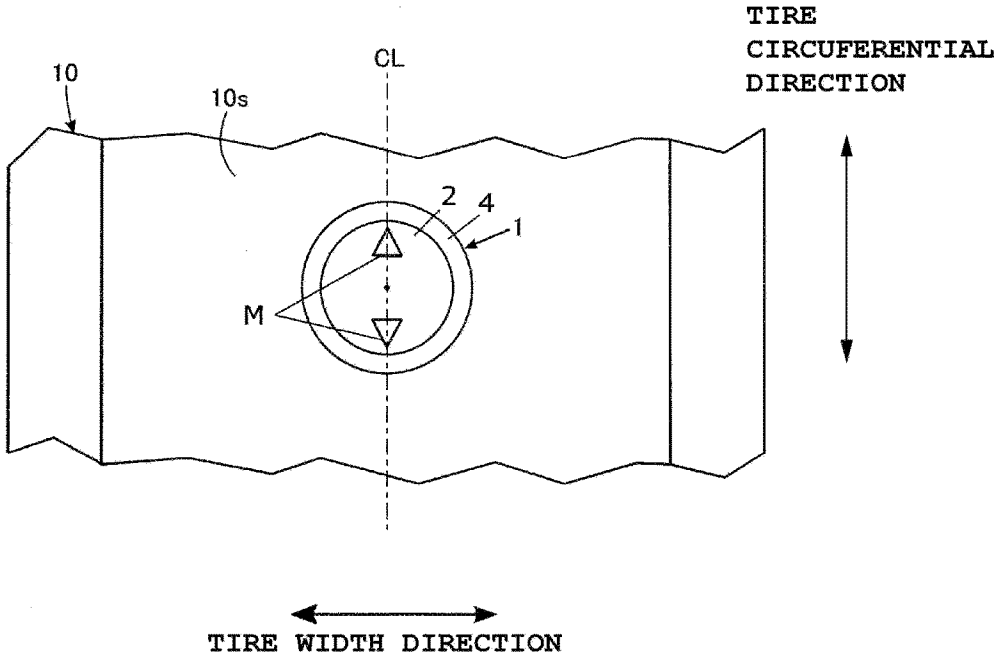


FIG.1B



Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 002

FIG.2

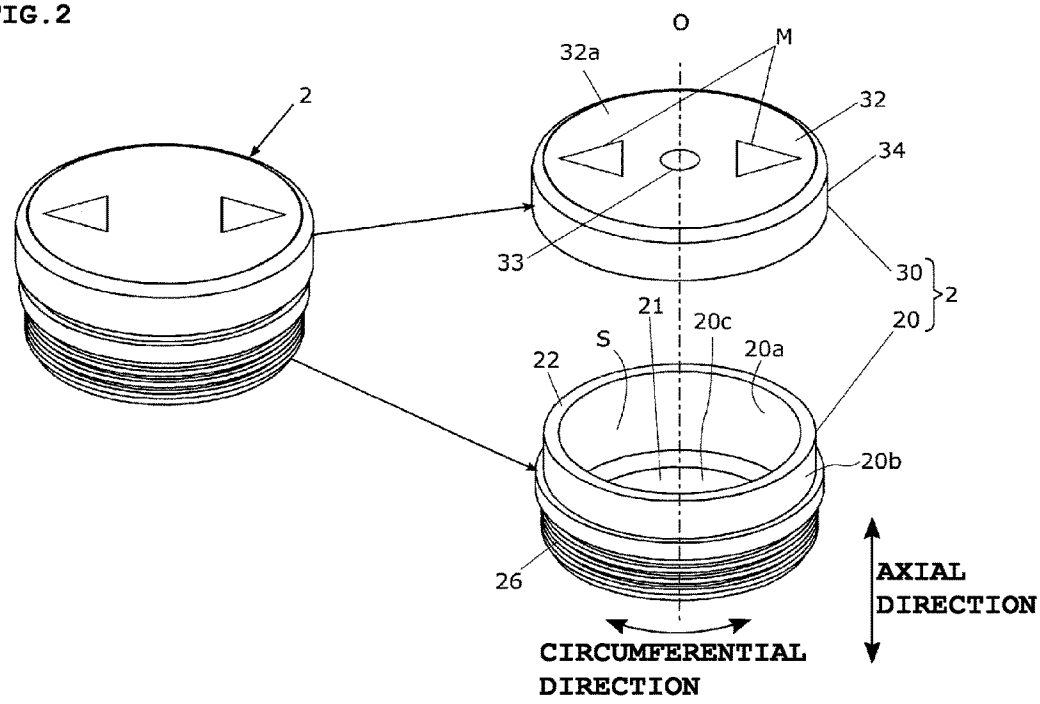


FIG.3A

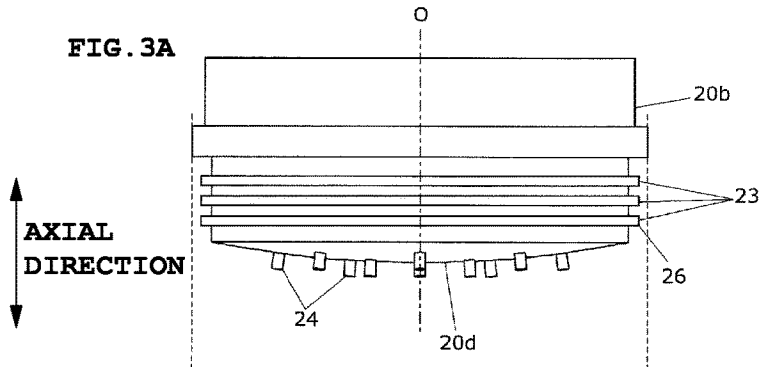


FIG.3B

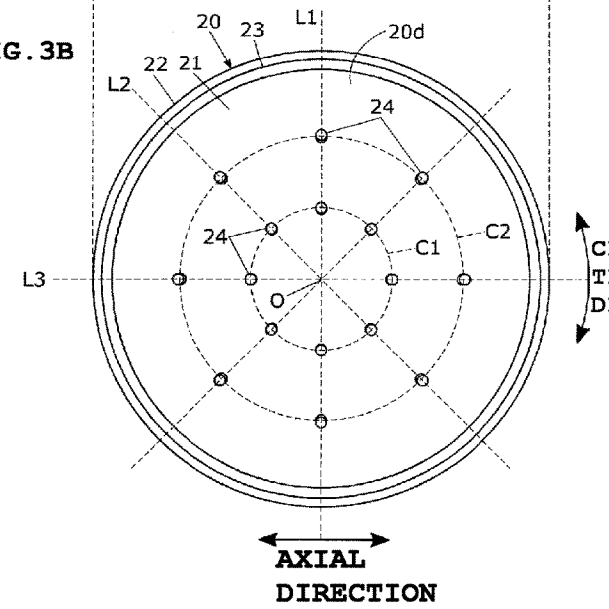


FIG.3C

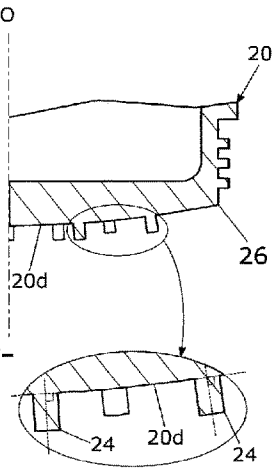


FIG.4A

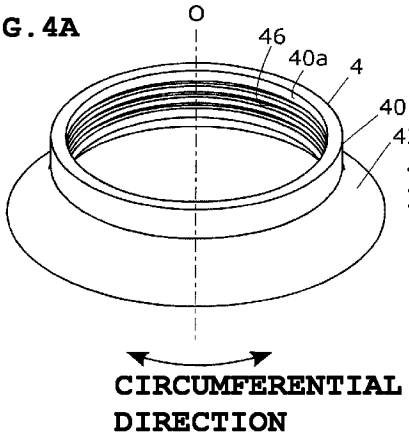


FIG.4B

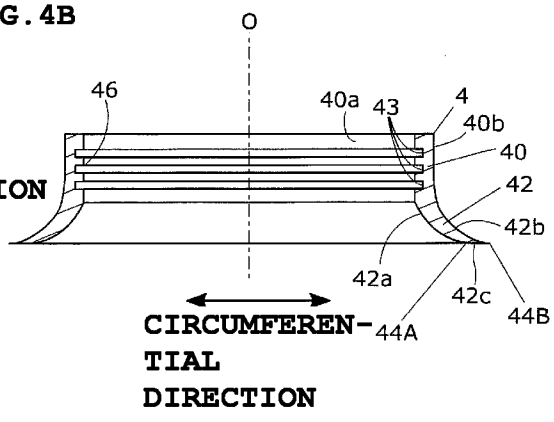


FIG.4C

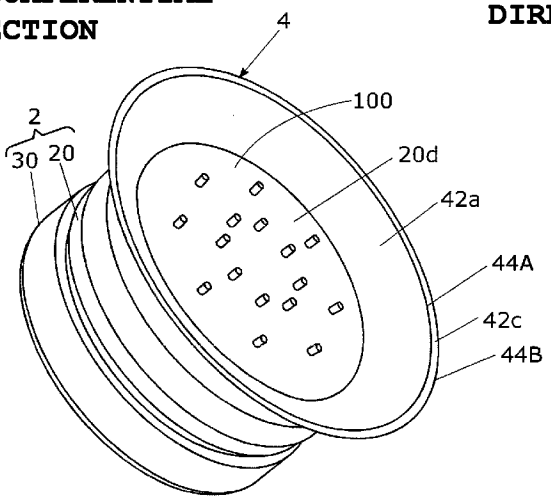
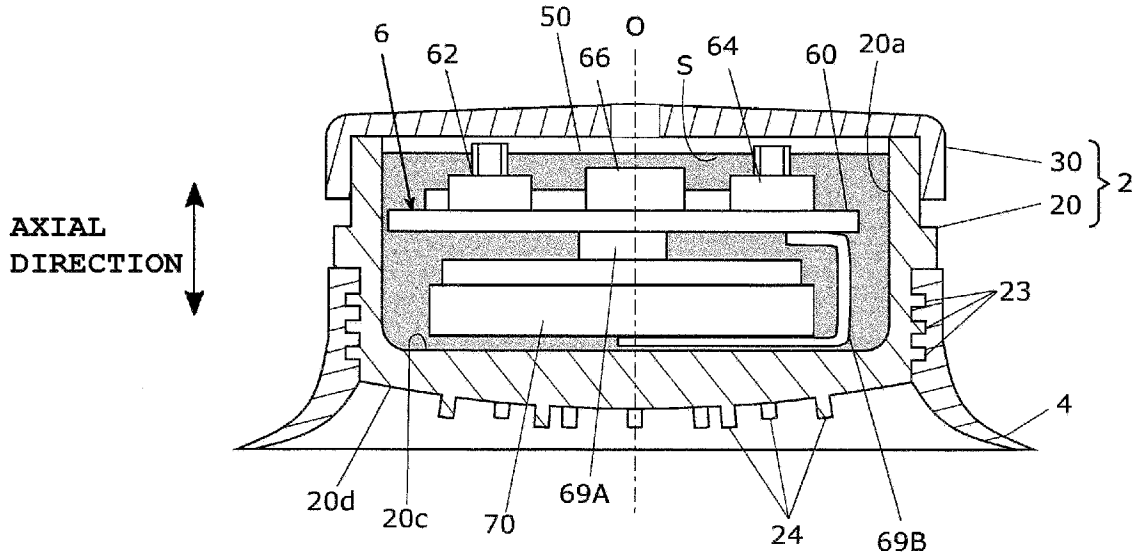


FIG.5



Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 004

FIG.6A

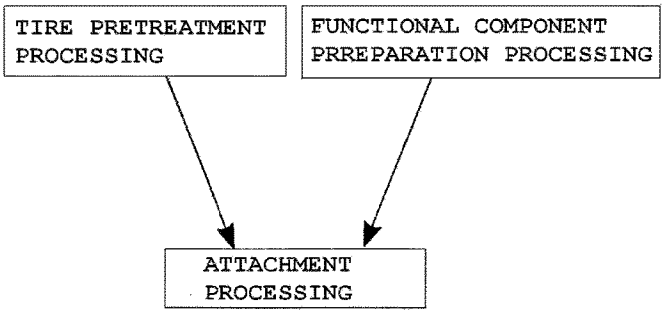


FIG.6B

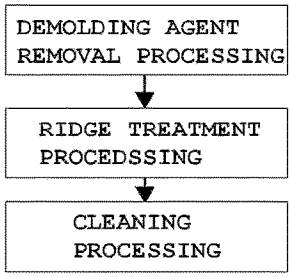


FIG.7

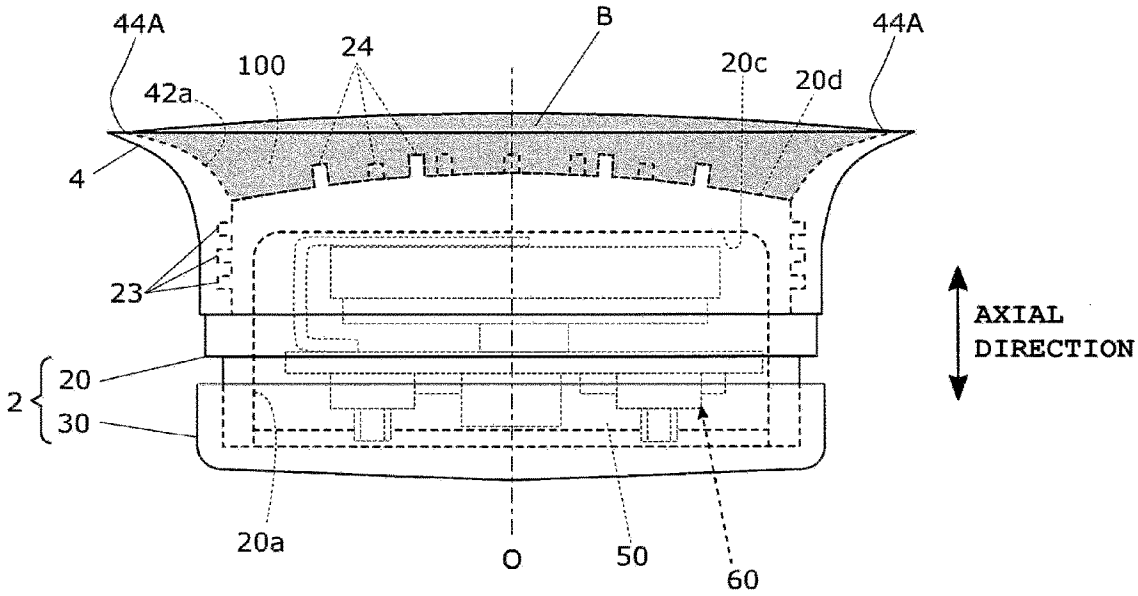


FIG.8

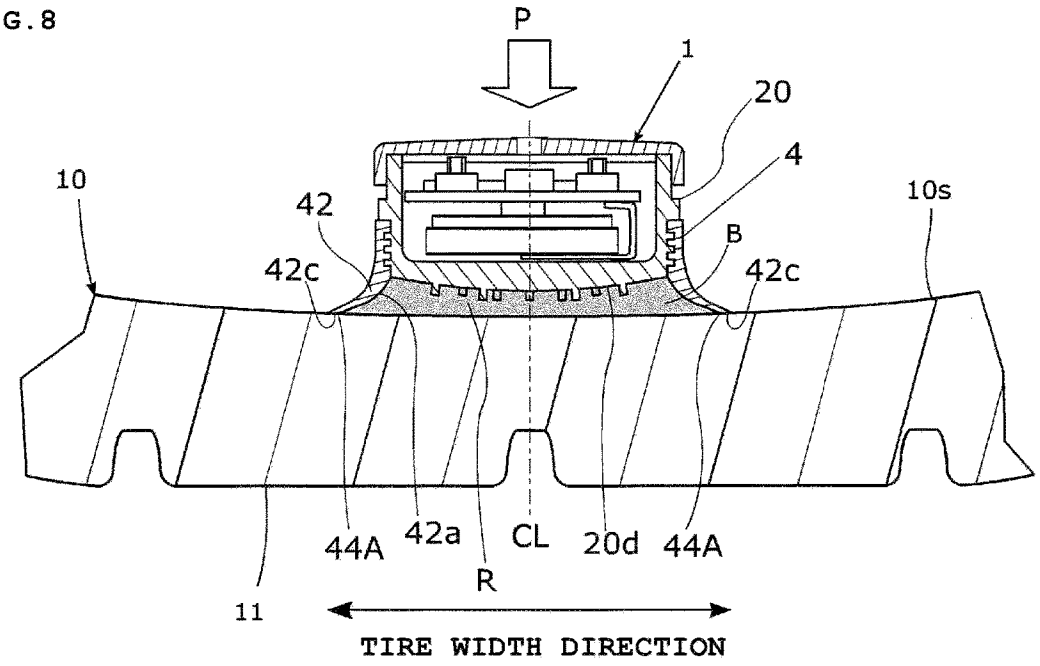

P
1
20
4
10
42
10s
B
42c
42c
44A
42a
CL
20d
44A
R
11
TIRE WIDTH DIRECTION

FIG.9

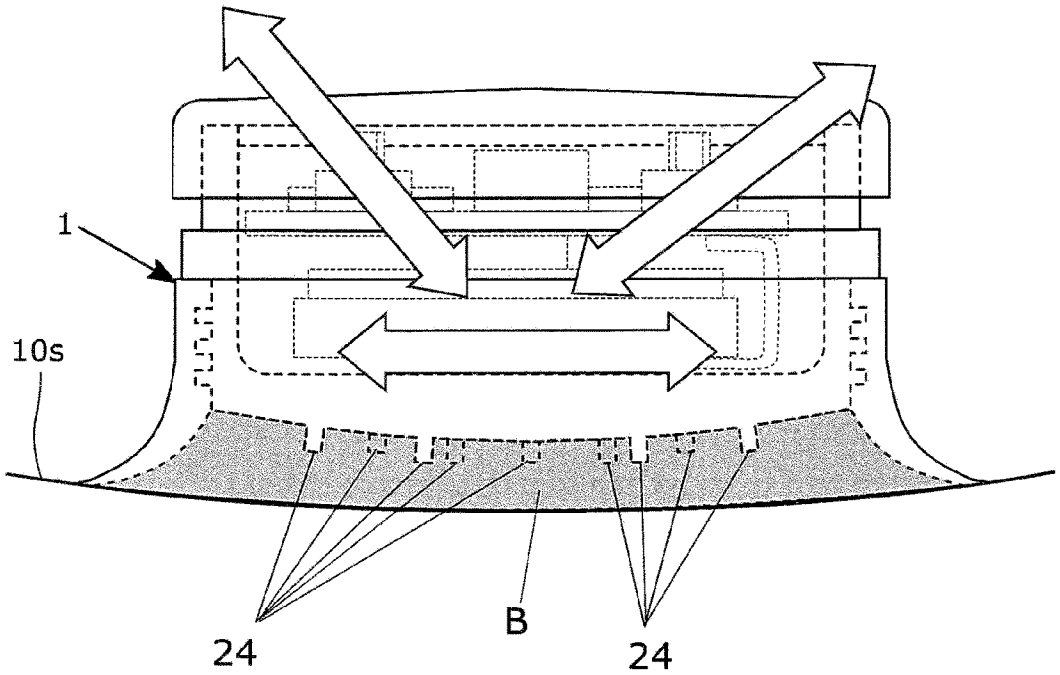

1
10s
B
24
24

FIG.10A

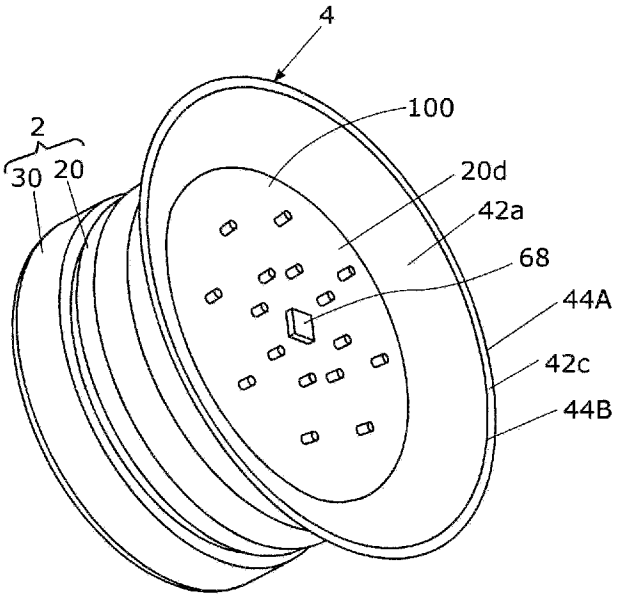
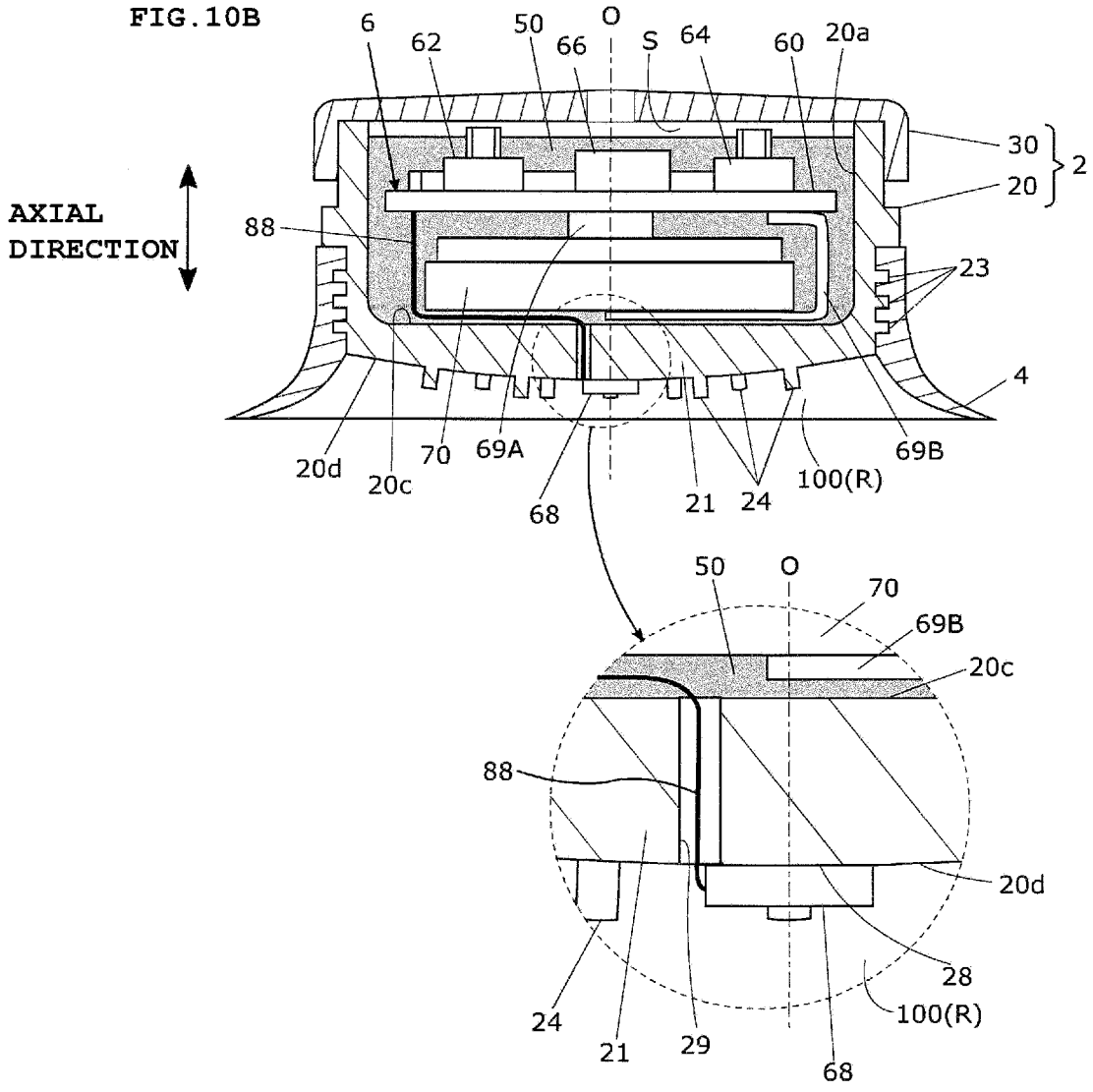


FIG.10B



Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 007

FIG.11

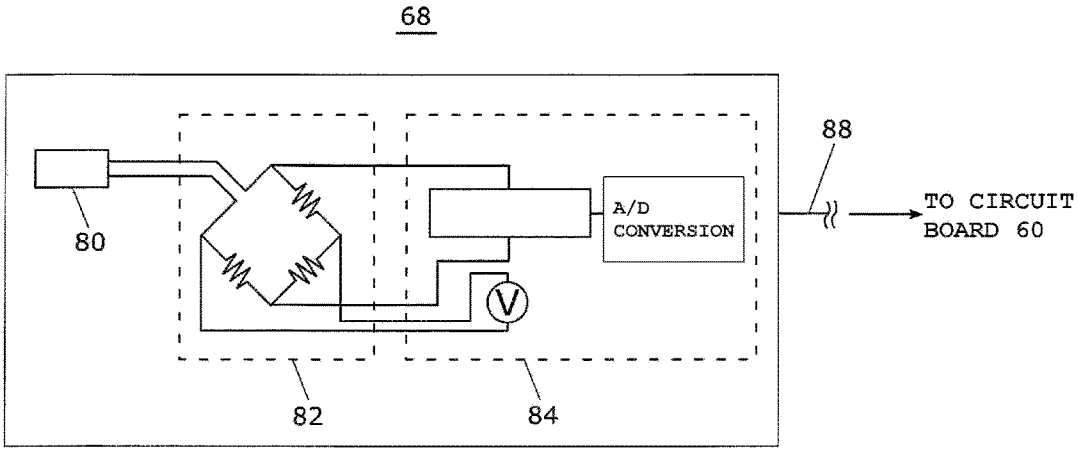


FIG.12

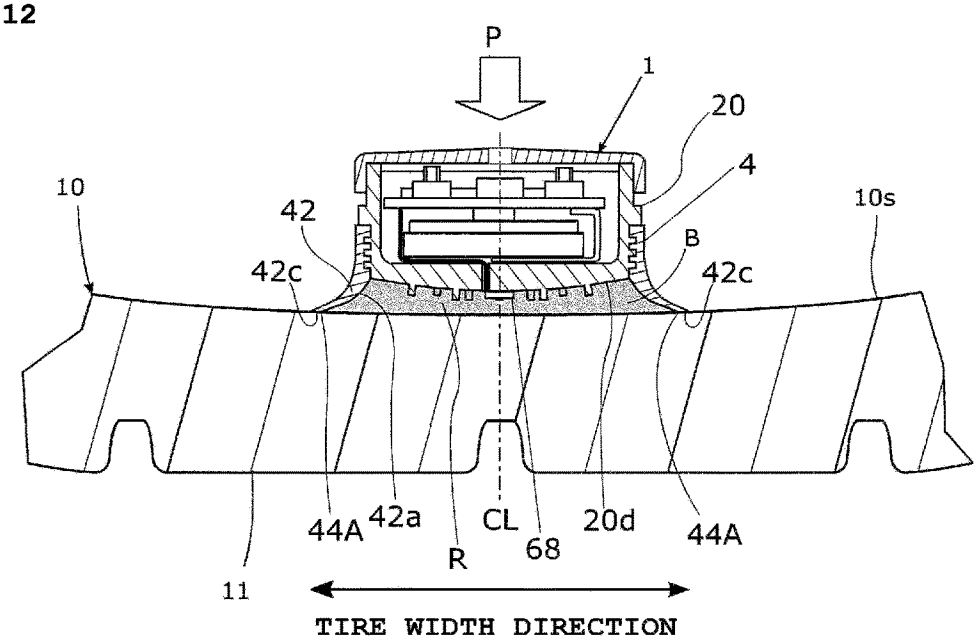
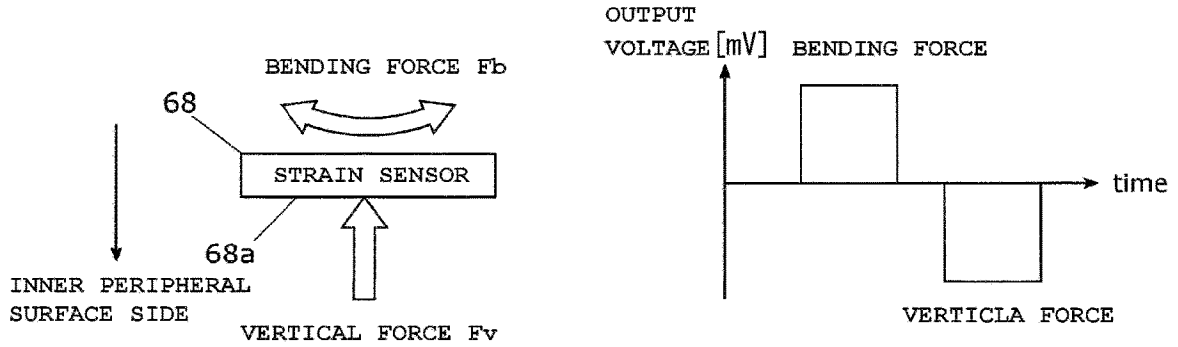


FIG.13



Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 008

FIG.14

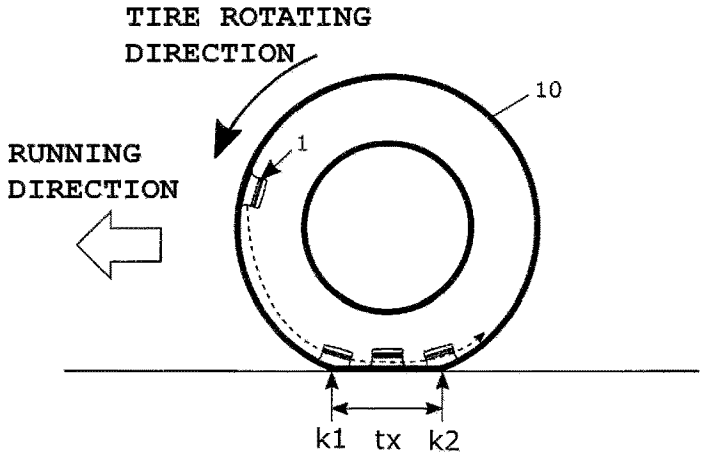


FIG.15

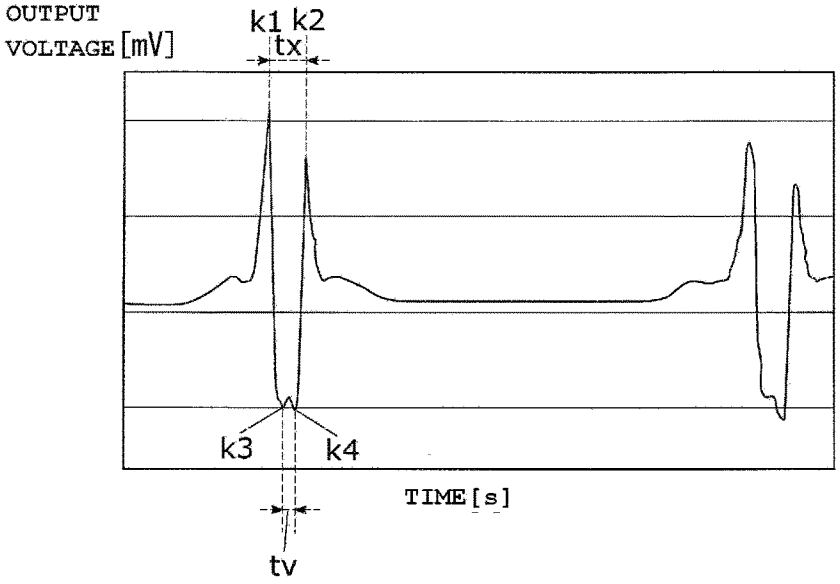
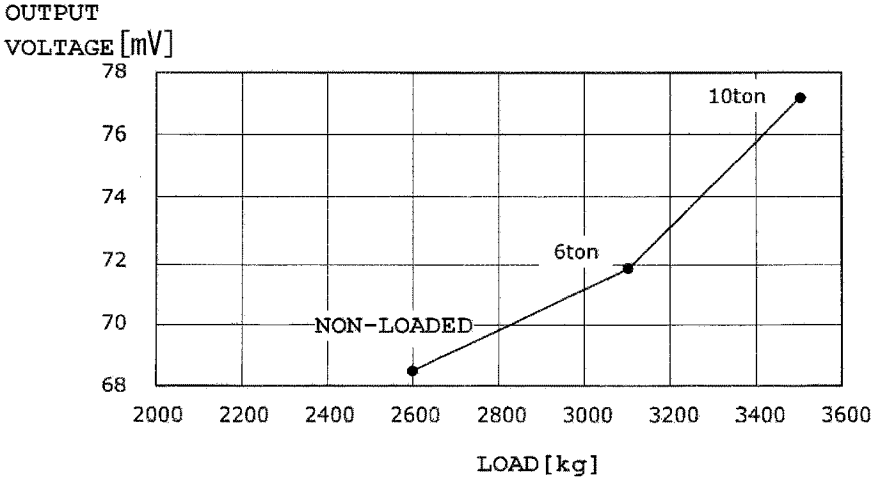


FIG.16



Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 009

FUNCTIONAL COMPONENT, STRUCTURE FOR ATTACHING FUNCTIONAL COMPONENT TO TIRE, AND TIRE

TECHNICAL FIELD

[0001] The present invention relates to a functional component or the like that can be attached to a tire.

BACKGROUND ART

[0002] Conventionally, there has been known an attachment structure for fitting a functional component having an electronic component housed in a case (housing) thereof for acquiring a use status of a tire, into a patch member provided on an inner surface of the tire (Patent Document 1).

CITATION LIST

Patent Document

[0003] Patent Document 1: Japanese Unexamined Patent Application Publication No. 2013-226853.

SUMMARY OF THE INVENTION

Technical Problem

[0004] However, in the conventional attachment structure, since the functional component is separable from the tire, the functional component cannot be used as a management tag in which information on individual tires is recorded, such as RFID or the like, for example. In addition, since a total weight of the functional component is a sum of a weight of the housing and a weight of the patch member, the weight tends to be high due to a size, a shape and an internal structure of the patch member. Furthermore, the production cost of the functional component is a sum of a production cost of the housing and a production cost of the patch member. Specifically, the patch member is required to be vulcanized and adhered to the inner surface of the tire by providing a thin rubber layer called an adhesive layer on an adhesive surface of a base member made by vulcanizing and molding rubber, and due to the increase in the work process, the patch member tends to be costly. As a measure to solve these problems, it is conceivable to omit the patch member and bond the housing directly to the inner surface of the tire using an adhesive agent. However, since tires are repeatedly deformed when coming into contact with the road surface, simply adhering the housing may cause it to come off the inner surface of the tire, or the housing may crack due to the impact at the time of contacting the ground, or the electronic component inside the housing may be damaged. Therefore, in order to prevent these problems, it is necessary to bond the housing to the inner surface of the tire by the adhesive agent with a sufficient thickness.

[0005] The present invention has been made in view of the above-mentioned problems, and aims at providing a functional component or the like that can secure, when the functional component is attached to the tire, sufficient thickness of the adhesive agent and that can improve the adhesive strength.

Solution to Problem

[0006] As the functional component for solving the above-mentioned problems, there is provided a functional component in which an electronic component capable of acquiring information inside a tire is housed and which is attachable to an inner peripheral surface of the tire, the functional component including a housing having a housing part for housing the electronic component and a bottom surface facing the inner peripheral surface of the tire, and a tubular part extending from a peripheral edge of the bottom surface toward the inner peripheral surface.

[0007] Furthermore, as the structure for attaching the functional component for solving the above-mentioned problems, there may be provided a structure for attaching, to a tire, the functional component described above, in which the end part of the tubular part is abutted against the inner peripheral surface of the tire, and an adhesive agent is filled in a filling space enclosed by an inner peripheral surface of the tubular part, the bottom surface of the housing and the inner peripheral surface of the tire.

[0008] In addition, as the structure of a tire for solving the above-mentioned problems, there may be provided a tire in which the functional component is attached to the inner peripheral surface of the tire by the attachment structure described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIGS. **1**A and **1**B are diagrams illustrating a functional component attached to a tire.

[0010] FIG. **2** is a perspective view of a housing.

[0011] FIGS. **3**A to **3**C are plan views and a partial cross-sectional view of a housing case.

[0012] FIGS. **4**A to **4**C are external perspective views and a cross-sectional view of a skirt.

[0013] FIG. **5** is a cross-sectional view of the functional component.

[0014] FIGS. **6**A and **6**B are diagrams illustrating the attachment process.

[0015] FIG. **7** is a diagram illustrating a filled state of an adhesive agent.

[0016] FIG. **8** is a diagram illustrating the adhesion to the tire.

[0017] FIG. **9** is a diagram illustrating the action of convex parts FIGS. **10**A and **10**B are an external perspective view and a cross-sectional view of a functional component according to another embodiment.

[0018] FIG. **11** is a diagram illustrating a schematic configuration of a strain sensor and its output.

[0019] FIG. **12** is a diagram illustrating the adhesion to the tire.

[0020] FIG. **13** is a diagram illustrating the output of the strain sensor.

[0021] FIG. **14** is a diagram illustrating positions of the functional component during rotation of the tire.

[0022] FIG. **15** is a diagram illustrating an example of the strain detected by the strain sensor during rotation of the tire.

[0023] FIG. **16** is a diagram illustrating a change in a loaded state of a vehicle.

[0024] Hereinafter, the present invention will be described in detail through embodiments of the invention, but the following embodiments are not intended to limit the invention(s) set forth in the claims. Furthermore, not all combinations of the features described in the embodiments are essential to the solving means of the invention, and selectively employed configurations are included.

Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 010

DESCRIPTION OF EMBODIMENTS

[0025] FIGS. **1**A and **1**B are diagrams illustrating an attachment state of a functional component **1** attached to a tire **10**. As illustrated in FIG. **1**A, the tire **10** is assembled to a wheel rim **15**, and an inner space of the tire **10** is filled with gas such as air.

[0026] As illustrated in FIGS. **1**A and **1**B, the functional component **1** is fixed by an adhesive agent B to an inner surface (inner peripheral surface **10***s*) of the tire **10** and is disposed in the center in a width direction of the inner peripheral surface **10***s* that is a back side of a tread **11**, which contacts with a road surface, of the tire **10**.

[0027] The functional component **1** has a housing (housing part) **2**, a skirt (tubular part) **4** and a module **6**. Incidentally, the type of the tire **10** to which the functional component **1** is to be attached is not particularly limited, but the functional component **1** is attached mainly to tires of automobiles traveling on ordinary paved roads (general roads and highways) such as passenger cars, trucks and buses, and of aircraft, and the like.

[0028] FIG. **2** is a perspective view of the housing **2**. FIGS. **3**A to **3**C are plan views and a partial cross-sectional view of a housing case **20** of the housing **2**. As illustrated in FIG. **2**, the housing **2** includes the housing case **20** having a housing space S (housing part) for a module **6**, and a cap **30** functioning as a lid member for the housing case **20**, and is formed in a generally disk shape by combining the housing case **20** and the cap **30** together. For the housing case **20** and the cap **30**, synthetic resin or the like is employed, for example, from the viewpoint of weight reduction and the strength of the functional component **1**.

[0029] As illustrated in FIG. **2**, the housing case **20** is formed, in a bottomed cylindrical shape with an opening on one side, by a circular bottom part **21** and a peripheral wall part **22** extending along the outer periphery from the outer peripheral edge of the bottom part **21** and rising annularly from the bottom part **21**. In the housing case **20**, a housing space S that can house the module **6** is formed by an inner bottom surface **20***c* of the bottom part **21** and an inner peripheral surface **20***a* of the peripheral wall part **22**. In the following description, terms such as an axial direction, a circumferential direction and a radial direction will be used with an axis O of the peripheral wall part **22** as a reference.

[0030] As illustrated in FIGS. **3**A to **3**C, a skirt attachment part **26**, to which a skirt **4** described later can be attached, is formed on an outer peripheral surface **20***b* of the peripheral wall part **22**. The skirt attachment part **26** is configured by a plurality of annular convex parts **23** formed on a lower half of the peripheral wall part **22**. The annular convex part **23** is an annular member extending over the circumferential direction of the outer peripheral surface **20***b*, and is provided in plural numbers (three in the present embodiment) at a predetermined interval in the axial direction. Incidentally, the annular convex parts **23** may be configured to extend intermittently in the circumferential direction without extending over the entire circumference.

[0031] On the inner bottom surface **20***c* of the bottom part **21**, a support means such as a protrusion, which is not shown in the figure, is formed for preventing the module **6** from directly contacting the inner bottom surface **20***c*. As illustrated in FIG. **3**B, an outer bottom surface **20***d* of the bottom part **21** is formed in a convexed shape where a central part of the outer bottom surface **20***d* is convexed outwardly in the axial direction than the outer peripheral edge side of the outer bottom surface **20***d*. The outer bottom surface **20***d* is a surface that faces the inner peripheral surface **10***s* of the tire **10** when attached on the inner peripheral surface **10***s* of the tire **10**. In more detail, the outer bottom surface **20***d* is formed in a spherical shape having a predetermined radius of curvature and of which center of curvature is set on the axis O. Incidentally, the bulging shape of the outer bottom surface **20***d* is not limited to the spherical shape. For example, it may be a polygonal pyramid shape such as a cone or a square pyramid with the position of the apex being set on the axis O, or any other curved shape such as a frustum formed by a part of an elliptic sphere. The outer bottom surface **20***d* does not need to be bulged out over its entirety, but may be partially bulged out in a curved shape as described above. For example, in a case where the tire outer diameter is large, the outer bottom surface **20***d* may be formed in a flat shape.

[0032] The outer bottom surface **20***d* is provided with a plurality of convex parts **24** projecting from the outer bottom surface **20***d* toward the inner peripheral surface **10***s* of the tire **10**. As illustrated in FIG. **3**B, the plurality of convex parts **24** are provided at positions where two concentric circles C**1**; C**2** of different diameters centered on the axis O penetrating the outer bottom surface **20***d* intersect a plurality of radial lines L**1** to L**3** extending in the radial direction from the axis O. Furthermore, as illustrated in FIG. **3**C, the convex parts **24** are formed to project in the normal direction of the outer bottom surface **20***d* at each position. That is, the convex parts **24** are formed radially about the axis O of the outer bottom surface **20***d* and at even intervals in the circumferential direction (even intervals about the axis O). The length of the convex parts **24** extending from the outer bottom surface **20***d* may be set appropriately, namely, the length may be such that the convex parts **24** do not protrude beyond a distal end **44**A of the skirt **4** described later when the skirt **4** is attached to the housing case **20**. In the present embodiment, the convex parts **24** are formed in a columnar shape, but the shape of the convex parts **24** is not limited to the columnar shape. Instead of the convex parts **24** protruding from the outer bottom surface **20***d*, concave parts may be formed that recess from the outer bottom surface **20***d* toward the inner bottom surface **20***c* side. The convex parts and the concave parts may also be formed in a combined manner.

[0033] The concave parts may be formed, for example, like dimples of a golf ball.

[0034] As illustrated in FIG. **2**, a cap **30** has a circular ceiling part **32** and a peripheral wall part **34** extending along an outer peripheral edge of the ceiling part **32**. On an outer side surface **32***a* of the ceiling part **32**, attachment marks M are formed to indicate a direction for attaching the functional component **1** to the tire **10**. The attachment marks M are indicated, for example, by engraving or printing. As illustrated in FIG. **1**B, the attachment marks M show that the functional component **1** is to be attached on the inner peripheral surface **10***s* of the tire **10** in such a manner that the arrows are oriented in the tire circumferential direction. The direction indicated by the attachment marks M may be set appropriately in accordance with a detection direction of the module **6**. Furthermore, a hole **33** penetrating in the axis O direction is formed in the ceiling part **32**. The hole **33** allows for communication between the housing space S of the housing case **20** and the outside when the opening of the housing case **20** is closed by the cap **30**. The peripheral wall part **34** has an inner diameter capable of enclosing the outer

periphery of the outer peripheral surface **20***b* of the peripheral wall part **22**. The cap **30** configured as described above is integrated with the housing case **20** by a fitting and fixing means or the like, which is not shown in the figure, in a state in which the attachment marks M provided on the outer side surface **32***a* are oriented in a predetermined direction with respect to the housing case **20**.

[0035] FIGS. **4**A to **4**C are perspective views and a cross-sectional view of the skirt **4** including the axis O. As illustrated in FIG. **1**A, the skirt **4** is attached to the above-described skirt attachment part **26** formed in the housing case **20**, and extends from the outer bottom surface **20***d* of the housing **2** toward the inner peripheral surface **10***s* side of the tire **10**. In other words, the skirt **4** extends in a direction away from the outer bottom surface **20***d* of the housing case **2**, with the outer bottom surface **20***d* of the housing **2** being a base point.

[0036] As illustrated in FIGS. **4**A to **4**C, the skirt **4** has an annular tubular part **40** and an enlarged part **42** extending from the tubular part **40** toward the inner peripheral surface **10***s* side. The tubular part **40** is formed in a cylindrical shape enclosing the skirt attachment part **26**. Annular recesses **43** extending along the circumferential direction and recessed in the radial direction are formed on an inner peripheral surface **40***a* of the tubular part **40**. The annular recess **43** is provided in plural numbers (three in the present embodiment), extends over the inner peripheral surface **40***a* all the way around, and is formed so as to be able to be mated with the annular convex part **23** provided in the housing case **20**. In other words, the annular concave parts **43** are provided at intervals and in quantity corresponding to the annular convex parts **23**.

[0037] The enlarged part **42** is formed in a fun-like shape that is continuous from the tubular part **40**. An inner peripheral surface **42***a* of the enlarged part **42** is formed as a curved surface that, in the axial cross section, gradually expands in diameter from the outer peripheral edge of the outer bottom surface **20***d* of the housing case **20** toward the inner peripheral surface **10***s* side of the tire **10**. Furthermore, an outer peripheral surface **42***b* is formed, for example, as a curved surface that is smoothly continuous with the outer peripheral surface **40***b* of the tubular part **40** and gradually expands in diameter toward the inner peripheral surface **10***s* of the tire **10**. That is, the enlarged part **42** is formed in a generally trumpet shape that expands in diameter and extends from the outer bottom surface **20***d* of the housing case **20** toward the inner peripheral surface **10***s* side.

[0038] Furthermore, the thicknesses of the inner peripheral surface **42***a* and the outer peripheral surface **42***b* that form the enlarged part **42** are set in a tapered shape so that the thicknesses gradually become thinner toward end parts of the inner peripheral surface **10**S side in the axial direction. The distal end **44**A of the inner peripheral surface **42***a* and a distal end **44**B of the outer peripheral surface **42***b* are connected via a flat surface **42***c*. In other words, the flat surface **42***c* is an annular surface enclosed by the distal end **44**A of the inner peripheral surface **42***a*, the distal end **44**B of the outer peripheral surface **42***b* and a plane perpendicular to the axis O.

[0039] The skirt **4** is preferably made of an elastic material, for example, such as rubber or elastomer and the like, or a material having flexibility. The type of rubber is not particularly limited, and natural rubber and synthetic rubbers such as dienic rubber or non-dienic rubber are enumerated. Furthermore, when the rubber is used as the material, for example, the skirt **4** is in a state of having been vulcanized and is formed into a stable shape. In other words, the skirt **4** is in a complete state as a single part.

[0040] FIG. **5** is a cross-sectional view of the functional component **1** with the module **6** housed in the housing case **20**. As illustrated in FIG. **5**, the module **6** is configured to be able to be housed in the housing space S of the above-mentioned housing case **20**. The module **6** is provided with a circuit board **60** having electronic components mounted thereon and a battery **70**. The circuit board **60** includes the electronic components which are, for example, a plurality of sensors such as a temperature sensor **62**, a pressure sensor **64** and an acceleration sensor **66** and the like, each of which functions as a state acquiring means that acquires a state inside the tire, a transmitting means, which is not shown in the figure, for outputting detected values detected by each of the sensors **62**, **64** and **66** to the outside of the tire, a control means that controls operations of the plurality of sensors **62**, **64** and **66** and of the transmitting means, and a memory means that stores histories of the detected values detected by each of the sensors **62**, **64** and **66**; and metal terminals **69**A and **69**B for supplying power from the battery **70** to these components. Incidentally, the configuration of the circuit board **60** is not limited thereto.

[0041] The battery **70** is a so-called disk-shaped button battery, and is connected to the circuit board **60** by sandwiching each electrode between the metal terminals **69**A and **69**B provided on the circuit board **60**. The battery **70** is not limited to the button battery, but may also be a tubular battery, and its form is not particularly limited.

[0042] The circuit board **60** and the housing case **20** are provided with a positioning means, which is not shown in the figure, that are mutually fitted with each other. Whereby, a measurement direction of the acceleration sensor **66** relative to the housing case **20** is defined.

[0043] The temperature sensor **62** and the pressure sensor **64** measure, as respective measuring parts thereof are brought in communication with a tire air chamber via the hole **33** formed in the cap **30**, a temperature and a pressure in the tire air chamber, respectively.

[0044] The acceleration sensor **66** is a sensor capable of measuring acceleration in three axial directions, for example, the tire width direction, the radial direction and the circumferential direction (rotational tangential direction), and is mounted so that each measurement direction faces a predetermined direction relative to the circuit board **60**. The acceleration sensor **66** is preferably mounted on the circuit board **60** so as to be located on the axis O, when the circuit board **60** is housed in the housing case **20**.

[0045] The transmitting means is mounted on the circuit board as a transmitting circuit and transmits the measured temperature, the pressure, and the acceleration and so on to the outside of the tire via an antenna which is not shown in the figure. Signals such as the temperature, the pressure and the acceleration transmitted wirelessly from the transmitting means are received, for example, by a wireless circuit of a main unit provided in a vehicle, which is not shown in the figure, and information about states of the tire (the temperature, the pressure, or presence/absence of abnormality) are displayed on a display unit provided in the vehicle.

[0046] The control means is mounted on the circuit board **60** as a transmission circuit, and executes a predetermined program on the basis of, for example, the detection of

rotation (centrifugal force) of the tire **10** by the acceleration sensor **66**, and controls the operation of the transmitting means that transmits the temperature, the pressure and the acceleration inside the tire **10** detected by the temperature sensor **62**, the pressure sensor **64** and the acceleration sensor **66**. The memory means records the history of the temperature, the pressure and the acceleration inside the tire **10** detected by the temperature sensor **62**, the pressure sensor **64** and the acceleration sensor **66**, as well as manufacture information and quality information of the tire.

[0047] The module **6** configured as mentioned above is housed in the housing case **20** in the state that the battery **70** is connected to the circuit board **60**, and positioned so that the battery **70** faces the inner bottom surface **20***c* of the housing space S, and the measurement direction of the acceleration sensor **66** mounted on the circuit board **60** faces the predetermined direction relative to the housing case **20**.

[0048] As illustrated in FIG. **5**, the housing space S is filled with a potting material **50** so as to eliminate a gap between the module **6** and the inner bottom surface **20***c* and the inner peripheral surf the ace **20***a* forming the housing space S. Whereby, the entire module **6** is covered with the potting material **50**. Incidentally, even in the state of being filled with the potting material **50**, the communication between respective measurement parts of the temperature sensor **62** and the pressure sensor **64** and the tire air chamber is maintained. As a material of the potting material **50**, urethane-silicone resin or epoxy resin is preferable. By employing such a material to the potting material **50**, the potting material **50** can maintain sufficient resistance to forces received from the battery **70** and the circuit board **60** even when the tire **10** is rotating, especially when the tire **10** is rotating at a high speed.

[0049] FIGS. **6**A and **6**B are work process diagrams illustrating the process of attaching the functional component **1** to the tire **10**. As illustrated in FIG. **6**A, the process of attaching the functional component **1** to the tire **10** is largely composed of a process of pretreatment to the tire **10** (tire pretreatment process), a preparation process of the functional component **1** side (functional component preparation process), and an attaching process.

[0050] As illustrated in FIG. **6**B, the tire pretreatment process includes a mold release agent removal process, a ridge treatment process and a cleaning process. The mold release agent removal process is a process for removing a mold release agent adhering to the inner peripheral surface of the tire that has been vulcanized and molded, for example, spraying a spray-type degreasing agent to a predetermined position of the inner peripheral surface **10***s* of the tire **10** and wiping off the mold release agent.

[0051] The ridge treatment process is a process for adjusting (flattening) the ridge (convexity) formed on the inner peripheral surface **10***s* of the tire **10** by a bladder during vulcanizing-molding to a surrounding height, for example, polishing by buffing or the like using a rotating tool such as a leutor. In a case where this process cannot be performed, this process may be omitted. The cleaning process includes spraying a cleaning spray and drying using a dryer or the like after removing buffing grouts and the like.

[0052] As illustrated in FIG. **7**, in the functional component preparation process, an adhesive agent B is filled so that a concave filling part **100** formed by the outer bottom surface **20***d* of the housing **2** and the inner peripheral surface **42***a* of the skirt **4** is filled with the adhesive agent B. At this conjuncture, it is preferable that an amount of the adhesive agent B is adjusted to be flush with or past the distal end **44**A of the inner peripheral surface **42***a* of the skirt **4**.

[0053] As illustrated in FIG. **8**, in the attaching process, the distal end **44**A and the distal end **44**B, which are the end parts of the skirt **4** filled with the adhesive agent B in the filling part **100**, are pressed toward the inner peripheral surface **10***s* of the tire **10** with a predetermined force P in a state of being abutted, and then dried by blowing hot air of about 100° by, the dryer for a predetermined time, for example. The functional component **1** is thereby bonded to the inner peripheral surface **10***s* of the tire **10**. When pressing, care should be taken to avoid overflow of the adhesive more than necessary due to too much of the pressing force. If the adhesive agent overflows more than necessary, a bonding height cannot be maintained.

[0054] As discussed above, the functional component **1** is configured to be attached in a state that the adhesive agent B is densely filled in the filling space R enclosed by the outer bottom surface **20***d* facing the inner peripheral surface **10***s* of the tire **10**, the inner peripheral surface **42***a* of the skirt **4** that expands in diameter and extends in a tubular shape from the peripheral edge of the outer bottom surface **20***d* toward the inner peripheral surface **10***s*, and the inner peripheral surface **10***s* of the tire **10**.

[0055] Incidentally, it is preferable that the adhesive agent B has, for example, the following physical properties (characteristics). In order to fix the housing **2**, which is made of a material such as plastic resin, to the tire **10** which is made of a rubber-based material, the adhesive agent B needs to have a peel strength required for both of the materials. In the present embodiment, the indication of the peel strength was set at 500 times the weight of the functional component **1**. Specifically, if the weight of the functional component **1** is 30 g, 30 g×500 times=15,000 g, or 15 kg or more is set. Furthermore, since the tire **10** is an elastic body and the housing **2** is an inelastic body, it is preferable that the adhesive agent B has elasticity that can deform to follow deformation of the tire **10** so that the adhesive surface between the adhesive agent B and the tire **10** and the adhesive surface between the adhesive agent B and the housing **2** will not peel off due to the deformation of the tire **10** caused by running.

[0056] In order to get such elasticity, it is suitable that the hardness of the adhesive agent B is, for example, is about 40-70 (a dimensionless number) similar to that of the rubber forming the tire **10**.

[0057] Furthermore, it is preferable that the curing time of the adhesive agent B is as short as possible when taking the productivity into consideration. Specifically, it is preferable that the adhesive agent B is cured by heating with a dryer at a heating temperature of 60° C. or higher for one minute or more. For example, to exemplify a commercially available adhesive agent, Item No. TB1530B Hardness: A48 (durometer type A hardness) manufactured by ThreeBond Co., Ltd. may be applied. The hardness of the rubber of tire **10** is about HS50-80 (Shore hardness), and according to the conversion table between durometer hardness test values and Shore hardness test sites, A48≈HS48, so the hardness is close to that of the rubber of tire **10**, which is suitable. Incidentally, a dedicated adhesive agent having the physical properties described above may be used.

[0058] The explanation has been made, as to the property of the adhesive agent B, that it is preferable for the adhesive

agent B after curing to have elasticity close to the hardness of the tire **10**. In addition to this, the adhesive agent B is required to have a volume (capacity) for allowing deformation such as compression or elongation following the deformation of the tire **10**. Therefore, by solidifying the adhesive agent B having the above-described physical properties in the state of being kept in the filling space R without leaking, sufficient thickness of the adhesive agent B after curing can be secured.

[0059] As for the thickness of the adhesive agent B after solidification, although it depends on the size of the tire **10**, in order to set the thickness of the adhesive agent B to be in between 1 mm and 3 mm at the thinnest point, it is preferable to set a degree of buldging of the outer bottom surface **20***d* of the housing **2** and a length in the axis O direction to the distal end **44**A of the skirt **4** extending from the peripheral edge of the outer bottom surface **20***d* According to the present embodiment, the thickness of the adhesive agent B can be freely set according to the shape of the filling part **100**. However, if the thickness of the adhesive agent B is set too thick, the material cost of the adhesive agent B increases and it becomes a factor of increase in the weight, which may also be a factor of unbalance of the tire **10**, thus it is preferable to set the thickness within the above-described range.

[0060] As illustrated in FIG. **9**, because a plurality of convex parts **24** are provided, on the outer bottom surface **20***d* of the housing **2**, at even intervals radially in the circumferential direction, as shown by the arrows in the figure, even if forces in the left-right direction or diagonally up-and-down direction act on the housing **2** inside the tire **10**, the convex parts **24** function as spikes, so that the forces for peeling off the housing **2** and the adhesive agent B can be prevented from directly acting on the adhesion interface, hence the adhesive peeling strength can be improved.

[0061] As described above, the functional component **1** is fixed to the tire **10** by the adhesive agent B filled in the filling space R and integrated without being easily separated from the tire **10**, so that various histories of the tire **10** in use measured by the module **6** can be used as individual information.

[0062] In the above-described embodiment, the skirt **4** is formed to be trumpet-shaped or fun-like shaped so that the skirt **4** expands in diameter toward the inner peripheral surface **10***s*. However, the shape is not limited to these shapes, for example, the skirt **4** may be formed in a cylindrical shape, a conical shape, or the like. Also, although the housing **2** and the skirt **4** are separately formed and integrated, the housing case **20** forming the housing **2** may be integrated with the skirt **4**.

[0063] FIGS. **10**A and **10**B are respectively an external perspective view and a cross-sectional view of the functional component **1** according to another embodiment. In the above-described embodiment, the functional component **1** has been described as having the temperature sensor **62**, the pressure sensor **64** and the acceleration sensor **66**. However, as illustrated in FIGS. **10**A and **10**B, for example, the functional component **1** may be configured to have a strain sensor **68** that enables measurement of deformation of the tire **10**.

[0064] As illustrated in FIGS. **10**A and **10**B, the strain sensor **68** is mounted on the outer bottom surface **20***d* of the housing **2**. As illustrated in the figures, when the outer bottom surface **20***d* is formed to be spherical, the strain sensor **68** may be placed on the axis O, which is the most proximal position to the inner peripheral surface **10***s* of the tire **10**. By mounting the strain sensor **68** in this manner, the strain when the tire **10** is deformed in the circumferential direction, the width direction or the like can be detected isotropically. With respect to the strain sensor **68**, a wiring **88** is connected to the circuit board **60**, for example, via a through hole **29** formed in the bottom part **21** of the housing case **20**.

[0065] As illustrated in the enlarged view in FIG. **10**B, a sensor mounting part **28** of the outer bottom surface **20***d* to which the strain sensor **68** is mounted may be formed in a flat shape in part. The range of the flat shape is preferably about the size of the strain sensor **68**.

[0066] FIG. **11** is a diagram illustrating a schematic configuration of the strain sensor. As illustrated in FIG. **11**, the strain sensor **68** includes, for example, a strain gage **80**, a bridge circuit **82**, a strain amplifier **84** and so on. The strain gage **80** constitutes a part of the bridge circuit **82**. The bridge circuit **82** receives a voltage, for example, from the strain amplifier **84**, and outputs to the strain amplifier **84**, as a signal, a difference in voltage values resulting from the change in resistance values when the strain gage **80** detects the strain.

[0067] The strain amplifier **84** includes a signal amplifier circuit, an A/D converter, and a power supply part. The signal amplifier circuit amplifies a signal input from the bridge circuit **82**, and the A/D converter converts the amplified signal into a digital signal and outputs to the circuit board **60**. In other words, a voltage value corresponding to the amount of strain detected by the strain gage **80** is output as the digital signal to the circuit board **60**.

[0068] In the present embodiment, as the strain sensor **68**, a sensor chip configured as a rectangular so-called piezoresistive semiconductor is applied, in which the functions of the strain gage **80**, the bridge circuit **82** and the strain amplifier **84** are integrated into a single chip, for example. The strain sensor **68** is mounted on the outer bottom surface **20***d* of the housing **2** in such a manner that, for example, a measurement surface **68***a* is defined and the measurement surface **68***a* faces the inner peripheral surface **10***s* of the tire **10**.

[0069] As such, by making the strain sensor **68** as a semiconductor, the power consumption can be minimized and the power supply can be shared with other sensor **62** and so on. In addition, the reliability of measurement and durability can be improved.

[0070] FIG. **12** is a diagram illustrating a state in which the functional component **1** is bonded to the inner peripheral surface **10***s* of the tire **10**.

[0071] The functional component **1** is bonded, in a state where the strain sensor **68** is attached to the outer bottom surface **20***d*, to the inner peripheral surface **10***s* of the tire **10** by filling the filling space R (filling part **100**) formed by the outer bottom surface **20***d* and the inner peripheral surface **42***a* of the skirt **4** with the adhesive agent B. In other words, the strain sensor **68** is bonded to the inner peripheral surface **10***s* of the tire **10** in the state of being embedded in the adhesive agent B.

[0072] As described above, by mounting the strain sensor **68** to the tire **10** via the adhesive layer formed by the adhesive agent B, the strain associated with the deformation of the tire **10** can be suitably detected. In order to measure the strain of the rotating tire **10**, it is desirable to mount the

strain sensor directly on the tire **10**. However, although the strain of the tire **10** varies in a wide range depending on condition of the part of the tire **10**, the internal pressure, the temperature and so on, the amount of strain (deformation amount) of the tire **10** is generally larger than a measurement range that is measurable by the strain sensor **68**.

[0073] For example, the amount of strain of the tire **10** corresponds to the amount of deformation of 1% or more relative to the original shape, that is, corresponds to the amount of deformation of 1 mm or more of a material with a length of 100 mm. On the other hand, since the inner structure of the strain gage is made of a metal material, it is difficult for the strain sensor **68** to measure a large deformation, hence, the amount of strain measurable by the strain sensor **68** is 0.1% or less, namely, equivalent to the deformation amount of 0.1 mm of the material with the length of 100 mm. Therefore, even if bonding the strain sensor **68** directly to the surface of the tire, such as the inner peripheral surface **10***s* of the tire **10**, and trying to measure the deformation of the tire **10**, because the measurement range of the strain sensor **68** does not match the deformation amount of the tire **10**, the deformation cannot be measured.

[0074] In the present embodiment, the filling space R in which the strain sensor **68** is mounted is filled with the adhesive agent B having elasticity for fixing the functional component **1**. Namely, the strain sensor **68** is fixed at a height of about 1 mm to 3 mm away from the inner peripheral surface (surface) **10***s* of the tire **10** by the intervention of the adhesive agent B. With this configuration, for example, the adhesive agent B can alleviate the deformation strain of the tire **10** to 1/10 or less, which is generated every time the tire **10** contacts the road surface, and the deformation strain of the tire **10** can be appropriately conveyed to the strain sensor **68**.

[0075] In other words, as in the present embodiment, by providing the adhesive agent B between the strain sensor **68** and the inner peripheral surface **10***s* of the tire **10**, the adhesive agent B functions as a buffer part for adjusting the measurement range, and it is made possible that the deformation of the tire **10** is appropriately measured by the strain sensor **68**.

[0076] FIG. **13** is a diagram illustrating an output of the strain sensor **68**. FIG. **14** is a diagram illustrating positions of the functional component **1** during rotation of the tire **10**. As illustrated in FIG. **13**, the strain sensor **68** outputs a voltage value of a positive value when detecting a bending force Fb that causes the measuring surface **68***a* to warp, and outputs a voltage value of a negative value when detecting a vertical force Fv perpendicular to the measuring surface **68***a*. As illustrated in FIG. **14**, the bending force Fb during rotation of the tire **10** is detected in the vicinity of a step-in position k**1** where the tire **10** contacts the road surface and a kick-out position k**2** where the tire **10** leaves the road surface. The vertical force Fv is detected, for example, as a vertical force detection time tv shown in FIG. **15** or the like, which is a range in which the bending force Fb does not act, within the period from the step-in position k**1** to the kick-out position k**2** in which the tire **10** is in contact with the road surface.

[0077] FIG. **15** is a diagram illustrating an example of the strain detected by the strain sensor **68** during rotation of the tire. FIG. **16** is a diagram illustrating changes in a loaded state of the vehicle calculated on the basis of the strain detected by the strain sensor **68**. As illustrated in FIG. **14**, the strain sensor **68** moves its position in the tire circumferential direction as the tire **10** rotates, detects a deformation state of the tire **10**, and outputs a time-series signal indicating the deformation.

[0078] By processing the obtained signal by the processing means, which is not shown in the figure, provided in advance on the circuit board **60**, the load applied to the tire **10** can be calculated and its history can be recorded, for example.

[0079] Then, by transmitting load values calculated at each wheel of the tire mounted on the vehicle from the functional component **1** attached to each tire to the main unit provided in the vehicle, which is not shown in the figure, and calculating its combined value, the change in the total weight of the vehicle can be obtained, as illustrated in FIG. **16**.

[0080] The use of the bending force Fb and the vertical force Fv directly obtained by the strain sensor **68** is not limited to this, but may also be used for the wear of tire, for example.

[0081] According to such a configuration, by directly obtaining the bending force Fb and the vertical force Fv, for example, by detecting a peak of the bending force Fb, the step-in position k**1** and the kick-out position k**2** can be easily detected. Furthermore, because the ground contact time tx detected on the basis of the step-in position k**1** and the kick-out position k**2**, and the time, at which the vertical force Fv is detected, can be obtained by a simple calculation process, it is possible to improve the life of the battery and makes the life of the battery longer than the life of the tire until the tire reaches the limit of use.

[0082] In other words, in the method of estimating the wear of the tire, the load applied to the tire and so on, on the basis of the acceleration information detected by the acceleration sensor **66**, physical phenomena that cause the wear of the tire or the change in the load are obtained indirectly. Therefore, in order to obtain as highly precise result as possible that is trustable, an enormous amount of acceleration information and an extensive processing are required, which leads to severe consumption of the battery that is to be the power source of the functional component **1**, hence there is concern that the life of the functional component **1** tends to be easily shortened.

[0083] On the other hand, according to the above-described configuration, since the tire wear and the load can be calculated without the need for an extensive processing, it is possible to improve the life of the battery.

[0084] Incidentally, with regard to the sensors to be provided in the functional component **1**, that is, the temperature sensor **62**, the pressure sensor **64**, the acceleration sensor **66** and the strain sensor **68** may be selectively mounted on the board.

[0085] As described above, the functional component according to the embodiment of the present invention is a functional component in which an electronic component capable of acquiring information inside a tire is housed and which is attachable to an inner peripheral surface of the tire, the functional component comprising a housing having a housing part for housing the electronic component and a bottom surface facing the inner peripheral surface of the tire, and a tubular part extending from a peripheral edge of the bottom surface toward the inner peripheral surface.

[0086] According to this configuration, by filling an adhesive agent in the container having an opening on one side,

which is formed by the tubular part extending from the peripheral edge of the bottom surface of the housing toward the inner peripheral surface of the tire, placing the tubular side on the tire surface, and thereafter, curing the adhesive agent, the functional component can be bonded to the inner surface of the tire while securing the thickness of the adhesive agent.

[0087] As another configuration of the functional component, the tubular part may extend in diameter and expand from the peripheral edge of the bottom surface toward the inner peripheral surface. In addition, a convex part or a concave part may be formed on the bottom surface, or in a case where the convex part is formed on the bottom surface, a distal end of the convex part may be located closer to a side of the bottom surface than an end part of the tubular part. Furthermore, the bottom surface may be formed so as to bulge out toward the inner peripheral surface of the tire. Furthermore, a strain detecting means that detects strain of the tire may be provided on the bottom surface.

[0088] As a structure for attaching a functional component, the structure may be a structure for attaching, to a tire, the functional component described above in which the end part of the tubular part is abutted against the inner peripheral surface of the tire, and an adhesive agent is filled in a filling space enclosed by an inner peripheral surface of the tubular part, the bottom surface of the housing, and the inner peripheral surface of the tire.

[0089] Furthermore, as a structure of a tire, the structure may be such that the functional component is attached to the inner peripheral surface of the tire by the above-described attachment structure.

[0090] Although the present invention has been described using the embodiments, the technical scope of the present invention is not limited to the scope described in the above-described embodiments. It is clear to those skilled in the art that various modifications or improvements can be made to the above-described embodiments. It is apparent from the claims that such modifications or improvements may also be included in the technical scope of the present invention.

REFERENCE SIGN LIST

[0091] **1**: Functional component, **2**: Housing, **4**: Skirt, **6**: Module,

[0092] **10**: Tire, **48**: Potting material, **60**: Circuit board,

[0093] **70**: Battery, B: adhesive agent, S: housing space.

1. A functional component in which an electronic component capable of acquiring information inside a tire is housed and which is attachable to an inner peripheral surface of the tire, the functional component comprising:

a housing having a housing part for the electronic component and a bottom surface facing the inner peripheral surface of the tire; and

a tubular part extending from a peripheral edge of the bottom surface toward the inner peripheral surface.

2. The functional component according to claim **1**, wherein the tubular part expands in diameter and extends from the peripheral edge of the bottom surface toward the inner peripheral surface.

3. The functional component according to claim **1**, wherein a convex part or a concave part is formed on the bottom surface.

4. The functional component according to claim **3**, wherein a distal end of the convex part is located closer to a side of the bottom surface than an end part of the tubular part.

5. The functional component according to claim **1**, wherein the bottom surface bulges out towards the inner peripheral surface.

6. The functional component according to claim **1**, wherein a strain detecting means that detects strain of the tire is provided on the bottom surface.

7. An attachment structure for attaching, to a tire, the functional component according to claim **1**, wherein

the end part of the tubular part is abutted against the inner peripheral surface of the tire, and an adhesive agent is filled in a filling space enclosed by an inner peripheral surface of the tubular part, the bottom surface of the housing, and the inner peripheral surface of the tire.

8. A tire wherein the functional component is attached to the inner peripheral surface of the tire by the attachment structure according to claim **7**.

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Revvo's Exhibit 1006
Revvo v. Cerebrum
IPR2025-00632 - Page 016