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United States Patent [19][11] **Patent Number:** **6,076,623****Teraoka et al.**[45] **Date of Patent:** **Jun. 20, 2000**[54] **FOUR-WHEEL DRIVE VEHICLE POWER TRAIN**

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Kaisha, Japan*Primary Examiner*—Daniel G. DePumpo*Assistant Examiner*—James S. McClellan*Attorney, Agent, or Firm*—Graham & James LLP[21] Appl. No.: **08/965,728**[22] Filed: **Nov. 7, 1997**[30] **Foreign Application Priority Data**

Nov. 8, 1996 [JP] Japan 8-296778

[51] **Int. Cl.⁷** **B62B 1/00**[52] **U.S. Cl.** **180/233; 180/248; 180/249;**
180/250[58] **Field of Search** 180/233, 248,
180/249, 250[56] **References Cited****U.S. PATENT DOCUMENTS**

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[57] **ABSTRACT**

A first power train (T1) for driving a pair of front drive wheels (Wf1, Wf2) comprises a transmission (4) connected to an engine (2) and a front drive train (41f) connected to the drive wheels, the front drive train including a final reduction gear (43), and a second power train (T2) for driving a pair of rear drive wheels (Wr1, Wr2) comprises a rear transfer train (11) branched from the first power train, between the transmission and the front drive train, and a rear drive train (41r) connected to the rear drive wheels.

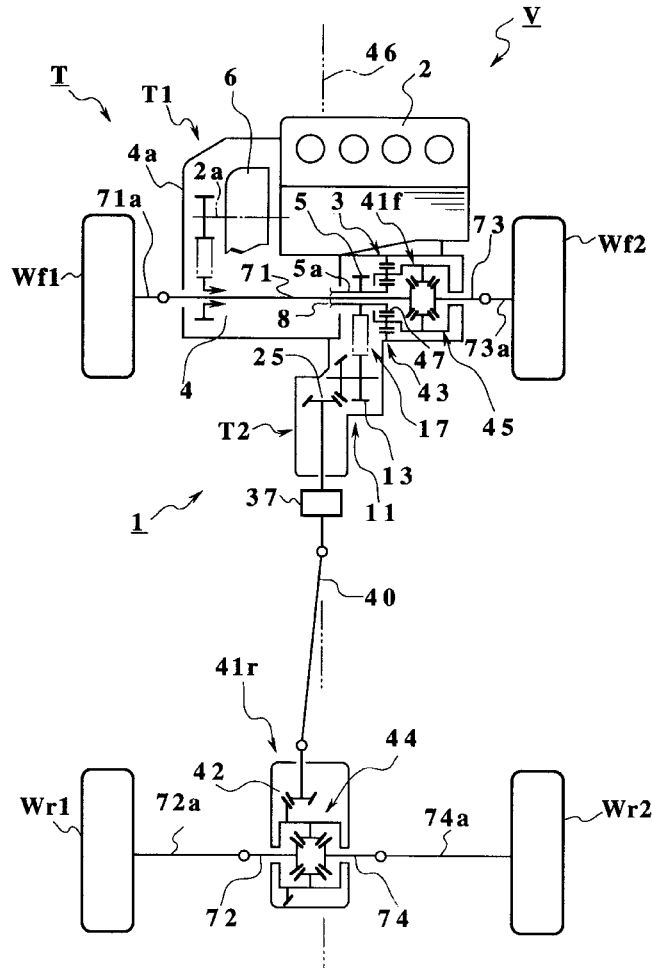
1 Claim, 6 Drawing Sheets

FIG. 1
PRIOR ART

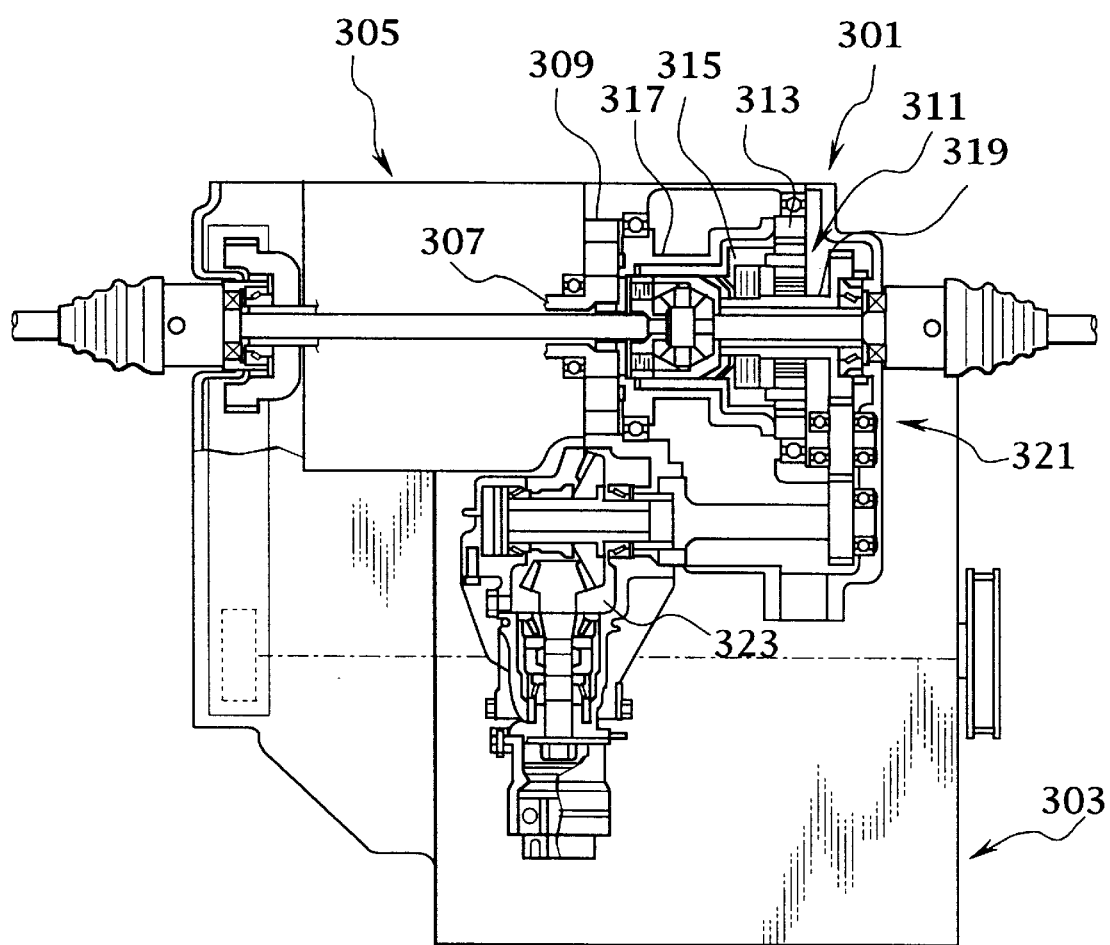


FIG. 2
PRIOR ART

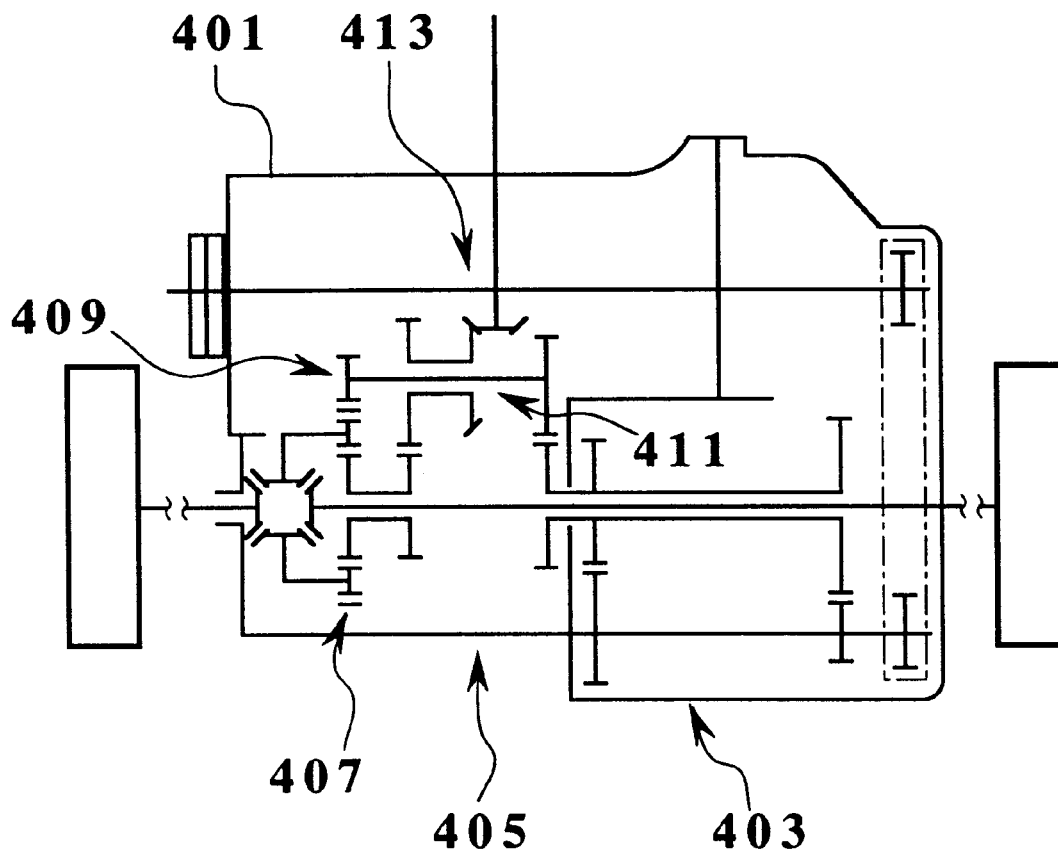


FIG.3

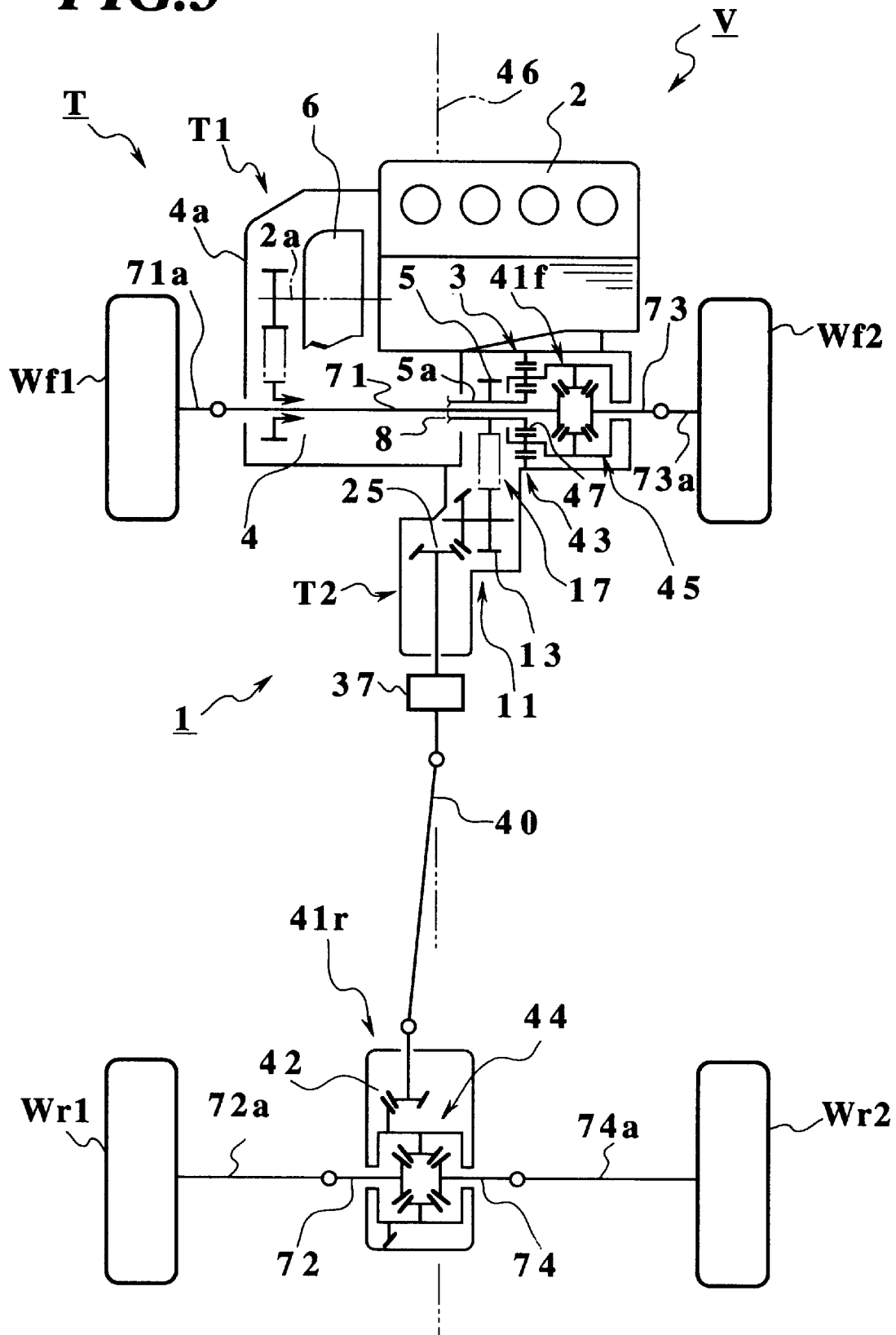


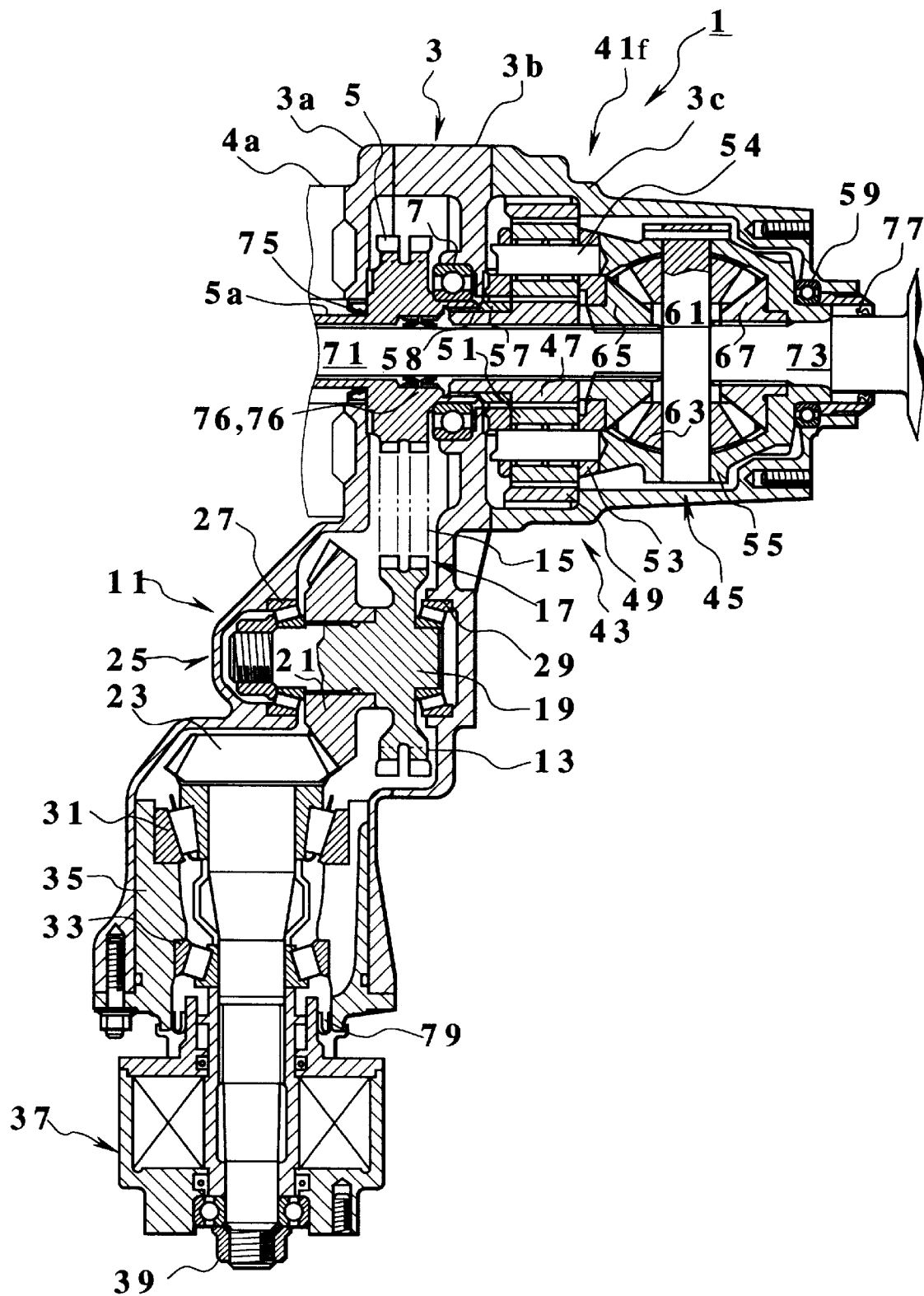
FIG. 4

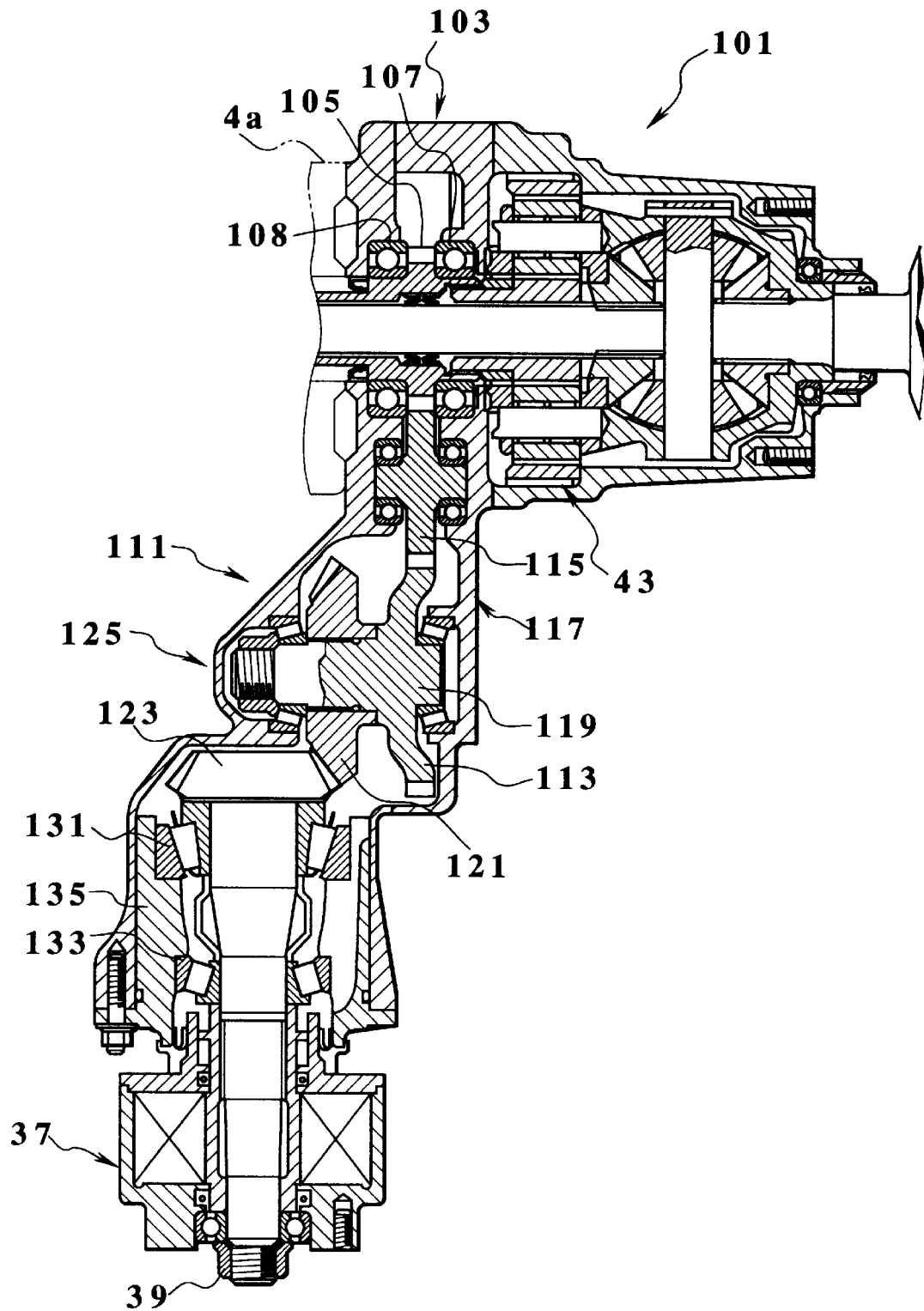
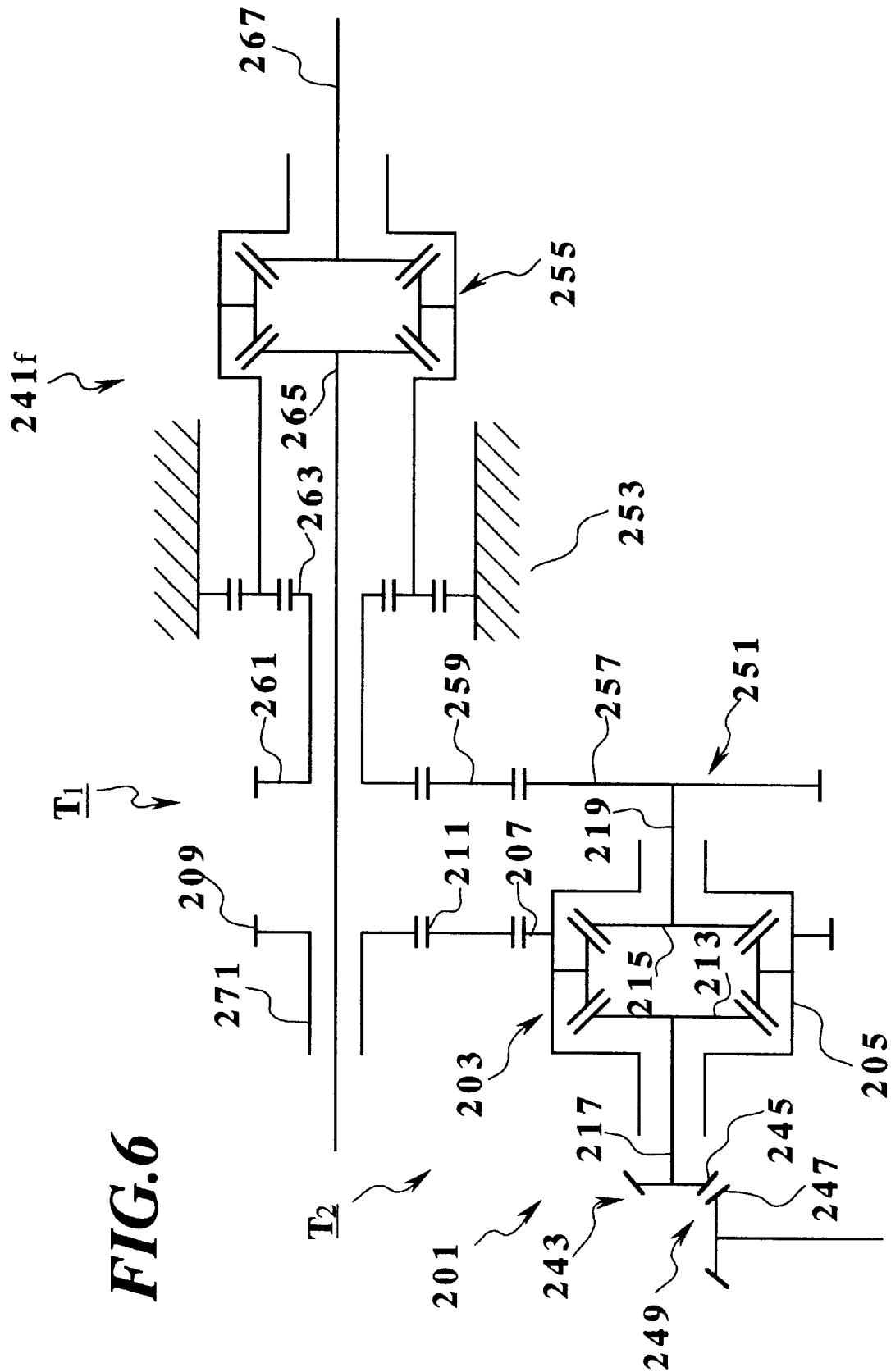
FIG. 5

FIG. 6



FOUR-WHEEL DRIVE VEHICLE POWER TRAIN

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a power train, and particularly, it relates to a power train for four-wheel drive vehicles.

2. Description of Relevant Art

There has been disclosed a four-wheel drive vehicle power train in Japanese Patent Application Laid-Open Publication No. 3-224829, and another four-wheel drive vehicle power train in U.S. Pat. No. 5,188,574.

The former power train is shown in FIG. 1, where it is designated by reference character **301**. The power train **301** includes a front drive train **309+311+317** and a rear transfer train **323**. The front drive train is arranged at an output end of a transmission **305** which is mounted in parallel to a transversely arranged horizontal engine **303** and put in a coaxial relation to left and right front axles. The drive train includes a planetary type final reduction gear **309**, a planetary type center differential gear **311** and a front differential gear **317**.

Drive torque from the transmission **305** is supplied from an output shaft **307** thereof, via the final reduction gear **309**, to a ring gear **313** of the center differential gear **311**, where it is shared to be distributed on the one hand from a pinion carrier **315** of the center differential gear **311** through the front differential gear **317** to the front axles, and on the other hand, from a sun gear output shaft **319** via a gear train **321** to the rear transfer train **323**, where it is changed in direction to be transmitted via a rear drive train to rear axles.

Drive torque is increased by a speed reduction at the final reduction gear **309**, before it enters the center differential gear **311**. The reduction gear **309** is indispensable to drive the front axles.

The latter power train is shown in FIG. 2, where it is designated by reference character **405**. The power train **405** has a front drive train **409+407+411** and a rear transfer train **413**. Drive power from an engine **401** is transmitted via a transmission **403**, where it is once changed in speed, to the front drive train, where it is again changed in speed at a final reduction gear **409** before it enters a center differential gear **407** of a planetary type.

In the conventional power trains described, the rear transfer trains are branched from the center differential gears **311**, **407** receiving increased torque to drive front axles and have their and associated components increased in size and weight. Such rear transfer trains may be mounted in a vehicle, with their centers of gravity transversely and/or longitudinally offset from a center of gravity of the vehicle, unfavorably displacing this gravity center, causing an undesirable distribution of loads to be imposed on driving road wheels.

The four-wheel drive vehicle power trains may have their components partially employed in two-wheel drive vehicle power trains. However, the existence of power input mechanisms which supply torque to center differential gears **311** and **407** results in the need for significantly different power train configurations for two-wheel drive and four-wheel drive vehicles, with a correspondingly low level of power train component interchangeability.

SUMMARY OF THE INVENTION

The present invention has been achieved with such points in view.

It therefore is an object of the present invention to provide a power train without a final reduction gear interposed between a transmission output shaft and a power transfer train, permitting the transfer train's and associated components to be reduced in size and weight, allowing for a favorable allocation of a center of gravity and a favorable distribution of loads to road wheels.

To achieve the object, a first aspect of the invention provides a power train for a vehicle with an engine and a total of four drive wheels, the power train comprising a first power train for driving a first pair of drive wheels, the first power train comprising a transmission connected to the engine, and a first drive train connected to the first pair of drive wheels, the first drive train including a first final reduction gear, and a second power train for driving a second pair of drive wheels, the second power train comprising a power transfer train branched from the first power train between the transmission and the first drive train, and a second drive train connected to the second pair of drive wheels.

According to the first aspect, decreased drive torque is transmitted through a power transfer train.

Accordingly, the power transfer train is permitted to be compact and light weight.

According to a second aspect of the invention depending from the first aspect, the power train further comprises a drive mechanism for branching the power transfer train from the first power train.

According to the second aspect, a drive mechanism affords an ensured power branching.

According to a third aspect of the invention depending from the second aspect, the drive mechanism comprises a chain drive member.

According to the third aspect, a power transfer train is allowed for flexible longitudinal displacement in design to have a center of gravity optimized in position.

According to a fourth aspect of the invention depending from the second aspect, the drive mechanism comprises a differential gear set.

According to the fourth aspect, a center differential gear may be designed compact with a light weight.

According to a fifth aspect of the invention depending from the second aspect, the power train further comprises a first cover for enclosing the first drive train, and a second cover for enclosing the drive mechanism, the second cover being separable from the first cover.

According to the fifth aspect, a power train has an increased interchangeability between a four-wheel drive and a two-wheel drive.

According to a sixth aspect of the invention depending from the first aspect, the transmission has an output shaft connected to the first drive train, and the first pair of drive wheels have axles thereof either extending through the output shaft.

According to the sixth aspect, a power transfer train is allowed for flexible transverse displacement in design to have a center of gravity optimized in position.

According to a seventh aspect of the invention depending from the first aspect, the first drive train includes a first differential gear set connected between the first final reduction gear and the first pair of drive wheels, and the second drive train includes a second final reduction gear connected to the power transfer train, and a second differential gear set connected between the second final reduction gear and the second pair of drive wheels.

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According to the seventh aspect, drive torque is increased when entering a differential gear set for power distribution between a respective pair of drive wheels.

According to an eighth aspect of the invention depending from the first aspect, the first pair of drive wheels comprise a pair of left and right front wheels of the vehicle, and the second pair of drive wheels comprise a pair of left and right rear wheels of the vehicle.

According to the eighth aspect, a first power train has a rear transfer train branched therefrom between a transmission and a front final reduction gear.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The above and further objects and novel features of the present invention will more fully appear from the following detailed description when the same is read in conjunction with the accompanying drawings, in which:

FIG. 1 is a section of a conventional power train;

FIG. 2 is a block diagram of another conventional power train;

FIG. 3 is a block diagram of a four-wheel drive vehicle with a power train according to an embodiment of the invention;

FIG. 4 is a section of the power train of FIG. 3;

FIG. 5 is a section of a power train according to another embodiment of the invention; and

FIG. 6 is a block diagram of a power train according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

There will be detailed below the preferred embodiments of the present invention with reference to FIGS. 3 to 6. Like members are designated by like reference characters.

FIG. 3 shows drive connections in a vehicle V equipped with a power train T including a power transfer device according to a first embodiment of the invention, and FIG. 4, a mechanical constitution of the transfer device.

As shown in FIG. 3, the vehicle V has a horizontal front engine 2 with a crankshaft axis 2a extending in a transverse direction of the vehicle, and a total of four drive wheels, i.e., a pair of left and right front wheels Wf1, Wf2 and a pair of left and right rear wheels Wr1, Wr2. The front wheels Wf1, Wf2 are driven with shafts 71a, 73a articulating on outer ends of left and right front axles 71, 73. Likewise, the rear wheels Wr1, Wr2 are driven with shafts 72a, 74a articulating on outer ends of left and right rear axles 72, 74.

Drive power generated at the engine 2 is transmitted as torque from a crankshaft of the engine 2 to the axles 71 to 74 in a differentially distributing manner through the power train T.

The power train T comprises a first power train T1 for driving the front axles 71, 73, and a second power train T2 for driving the rear axles 72, 74.

The first power train T1 comprises an automatic transmission gear box (hereafter sometimes "transmission") 4 composed of a planetary gear set and a multi-disc clutch, and a front drive train 41f that includes a front final speed reduction gear mechanism (hereafter sometimes "front final gear") 43 and a front differential gear set (hereafter sometimes "front differential") 45.

The second power train T2 comprises a rear transfer train 11 that includes a chain drive transfer mechanism 17, a bevel

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gear set 25 and a viscous coupling 37, a propeller shaft 40, and a rear drive train 41r that includes a rear final speed reduction gear mechanism (hereafter sometimes "rear final gear") 42 and a rear differential gear set (hereafter sometimes "rear differential") 44. The coupling 37 may be any power coupling of a revolution speed difference sensing type, such as of a fluid type or solid type, e.g. an oil pump coupling.

The transfer device is constituted as a power transfer unit 1 (FIG. 4) accommodate in a transfer housing 3, and comprises the front drive train 41f and the rear transfer train 11. In the embodiment, the second power train T2 is branched from the first power train T1. In a modification for use in a gasoline/battery hybrid car, first and second power trains may be joined at their intermediate points.

The transmission 4 is transversely installed behind the engine 2. Drive torque from the engine 2 is input through a torque converter 6 to the planetary gear set of the transmission 4, where it is once changed in speed to be output from an output gear 8 of which a shaft part is hollowed and operatively connected via the front drive train 41f to the left and right front axles 71, 73 aligned to be coaxial to the output gear 8. The left axle 71 is provided through the hollowed shaft part of the output gear 8.

As shown in FIG. 4, the transfer housing 3 comprises a left housing 3a, a central housing 3b and a right housing 3c. These housings 3a, 3b, 3c are mutually fastened tight. The left housing 3a is bolted to an output end of a transmission case 4a.

The left and central housings 3a, 3b cooperate with each other to define a space for accommodating therein a drive sprocket 5 as a torque sharing drive member of the transfer unit 1 and the remaining part of the rear transfer train 11 for a rearward transmission of torque to drive the rear axles 72, 74. The drive sprocket 5 has a transversely extending hollow shaft part 5a splined to the hollowed shaft part of the output gear 8 in the transmission 4.

The rear transfer train 11 has the chain drive transfer mechanism 17 including the drive sprocket 5, and the bevel gear set 25 directly connected to the transfer mechanism 17 and coupled via the viscous coupling 37 to a front end of the propeller shaft 40. A rear end of the propeller shaft 40 is connected to the rear drive train 41r comprised of the rear final gear 42 and the rear differential 44.

The right housing 3c accommodates the front drive train 41f supplying drive torque to the front axles 71, 73. The front drive train 41f has the front final gear 43 and the front differential 45 arranged coaxial relative to the drive sprocket 5.

The final reduction gear 43 in the front drive train 41f is a planetary type of which a sun gear 47 is arranged coaxial to the shaft part 5a of the drive sprocket 5 and splined to a right end thereof. In a modification for use to a two-wheel drive vehicle, the sun gear 47 may be directly splined to the output gear 8 of the transmission 4. The front differential 45 serves for a differential distribution of drive torque to and between the left and right front axles 71, 73.

The drive sprocket 5 is supported at the right end of the axial part 5a by a bearing 7 fixed to the central housing 3b. The sprocket 5 is driven by the output gear 8 of the transmission 4, to rotate about a common axis.

In the rear transfer train 11, an intermediate shaft 19 is driven to be rotated by the chain drive transfer mechanism 17 comprised of the drive sprocket 5, a driven sprocket 13 and a looped chain 15. The chain 15 is relaxed when applied over the sprockets 5 and 13, and becomes tensioned when

transmitting drive power. The intermediate shaft **19** has a bevel gear **21** splined to be forcibly fitted thereon, which gear **21** meshes with a bevel pinion **23**, changing the direction of a power path to convey torque toward the rear drive train **41r**. The intermediate shaft **19** is rotatably supported at both ends thereof by bearings **27**, **29** fixed to the housing **3**. The bevel gear set **25** is comprised of the bevel gear **21** and the bevel pinion **23**.

The bevel pinion **23** is rotatably supported by bearings **31**, **33** in a carrier **35**, and has the viscous coupling **37** rotatably assembled to a rear output part thereof by a nut **39**. The viscous coupling **37** serves as a differential limiting element of a revolution speed difference sensing type. A cylindrical housing of the coupling **37** is centered to a longitudinal hollow hub, which is spline-connected at a front end thereof to a rear end of the carrier **35**. An axial position of the hub is established by the nut **39**. Such the sub-assembly is fixed to the transfer housing **3** with bolts fastening the carrier **35**. The viscous coupling **37** is bolted at a rear outer part of its housing to a flange at the front end of the propeller shaft **40** to transmit torque to the rear drive train **41r**.

The planetary type final reduction gear **43** in the front drive train **41f** has the sun gear **47** splined at a left boss part thereof to be connected inside an enlarged right end part of the hollow shaft part **5a** of the drive sprocket **5**, and the front differential **45** of a bevel gear type is arranged on the right side of the front final gear **43**.

The final reduction gear **43** has a ring gear **49** serrated along an outer circumference thereof to be integrally fixed inside the right housing **3c** and kept from a relative rotation thereto, and a plurality of planet gears **63** intermeshing between the ring gear **49** and the sun gear **47**, which planet gears **51** are rotatably fitted on a corresponding number of planet support shafts **54** held at their relative angular positions by a planet shaft carrier **53**.

The planet shaft carrier **53** is integrally fixed or joined at a right half thereof to a left portion of a differential case **56** or gear carrier of the front differential **45**. A left half of the planet shaft carrier **53** is rotatably fitted to be supported by a ring **58** on the boss part of the sun gear **47**, with a bearing **57** interposed therebetween. A right boss part of the differential case **55** is rotatably fitted in and supported by a right end part of the right housing **3c**, with a bearing **59** interposed therebetween.

Drive torque supplied through the shaft part **5a** of the drive sprocket **5** to the front drive train **41f** is input to the front final gear **43**, where it is changed in speed in the way from the sun gear **47** integrally rotating with the drive sprocket **5** to the planet shaft carrier **53** where it is output. As the planet shaft carrier **53** is integrated with the differential case **55**, drive torque from the carrier is directly input to the front differential **45**.

The front differential **45** has accommodated in the case **55** a pinion shaft **61** integrally rotatable therewith, pinion gears **63** rotatably supported on the pinion shaft **61**, and mutually opposing left and right side gears **65**, **67** meshing with the pinion gears **63**. The left and right side gears **65**, **67** serve as output gears and are splined on inner ends of the left and right front axles **71**, **73**, respectively. The left axle **71** is provided thorough respective hollow shaft parts of the sun gear **47** in the front final gear **43**, the drive sprocket **5** and the output gear **8** of the transmission **4**.

The transfer housing **3** has a body of lubricant filled therein, and oil seals **75**, **76**, **77** and **79** are installed at appropriate points to prevent leakage.

The rear transfer train **11** is accommodated in a space defined by a combination of the left and central housings **3a**,

3b and separated from that defined within the right housing **3c** where the front drive train **41f** is installed, permitting a closer location to a vehicle centerline **46**.

Drive torque from the engine **2** is transmitted through the transmission **4**, where it is once changed in speed, and from the output gear **8** to the drive sprocket **5**, where it is shared to branch into the rear transfer train **11**, so that the rest is input to the front drive train **41f**.

Input torque to this drive train **41f** is changed in speed at the front final gear **43** and shared at the front differential **45** for a differential distribution to and between the left and right front axles **71**, **73**, permitting a differential rotation in dependence on a varying difference in resistance to drive torque therebetween.

Branched torque to the rear transfer train **11** is a fraction of the drive torque transmitted to the drive sprocket **5**, without experiencing a speed reduction and an associated torque increment that otherwise might have been effected at the front final gear **43**. The branched torque, which is thus smaller than a conventional, have smaller loads imposed on associated components such as the chain drive transfer mechanism **17** and the bevel gear set **25** on the way of power transference to the rear drive train **41r**.

It therefore becomes possible to make the components comprising the rear transfer train **11** as well as the rear drive train **41r** in its entirety, lighter in weight and smaller in size.

Moreover, the front drive train **41f** is wholly aligned with the transversely extending axles **71**, **73** and disposed near the vehicle centerline **46**, permitting an optimized transverse and/or longitudinal location of the center of gravity of the rear transfer train **11** employing the chain drive mechanism **17**.

Further, as the rear transfer train **11** is enclosed within the left and central housings **3a**, **3b** and the front drive train **41f** is enclosed within the left housing **3c**, these major component assemblies can adapt themselves well to unit construction, providing a high degree of drive train component interchangeability and an enhanced design commonality between two-wheel drive and four-wheel drive power trains.

FIG. **5** shows a power transfer device **101** of a four-wheel drive vehicle power train according to a second embodiment of the invention. This embodiment is analogous to the first embodiment, unless otherwise described or depicted.

The transfer device **101** has a drive gear **105** as an input member thereof, which gear **105** is rotatably supported at both transverse ends by a pair of left and right bearings **108**, **107** fixed in left and central sections of a transfer housing **103** and splined to be coaxially connected at a left end of a hollow shaft part thereof to an output gear of a transmission of which a housing **4a** is depicted in FIG. **5**.

The transfer device **101** comprises a front drive train including a front final reduction gear mechanism **43**, and a rear transfer train **111** including a gearing transfer mechanism **117**, a bevel gear mechanism **125** and a viscous coupling **37**. The transfer mechanism **117** comprises the drive gear **105**, an idler gear **115**, and a driven gear **113** integrated with an intermediate shaft **119** in a one-piece construction. The bevel gear mechanism **125** comprises a bevel gear **121** splined and forcibly fitted on the shaft **119**, and a bevel pinion **123** meshing with the bevel gear **121**. The viscous coupling **37** has a housing assembled to a carrier **135** rotatably supported by a pair of bearings **131**, **133**, and a hub axially positioned by a nut **39**.

The rear transfer train **111** is branched from a power train including the transmission and the front drive train, at the

drive gear **105** installed upstream of the front final gear **43**, achieving similar effects to the first embodiment.

FIG. 6 shows a power transfer device **201** of a four-wheel drive vehicle power train according to a third embodiment of the invention. This embodiment also is analogous to the first embodiment, unless otherwise described or depicted.

The transfer device **201** comprises part of a first power train **T1** including a center differential gear set (hereafter sometimes "center differential") **203** and a front drive train **241f** connected thereto, and part of a second power train **T2** including a rear transfer train **201** branched from the first power train **T1** at the center differential **203**.

The first power train **T1** includes a transmission of which an output shaft **271** has an output gear **209** connected via an idler gear **211** to a ring gear **207** of the center differential **203**, which gear **207** is integrated with a differential case **205** receiving drive torque transmitted from an engine.

The center differential **203** is a bevel gear type in which a pair of mutually opposing left and right output side gears **213**, **215** differentially output the torque received by the differential case **207**, so that this torque is shared to be distributed on the one hand through a left output shaft **217** to the rear transfer train **201** that includes a transverse transfer mechanism **243** connected to the left output shaft **217** and a longitudinal transfer mechanism **249** connected via a propeller shaft to a rear drive train for driving a pair of rear axles, and on the other hand, through a right output shaft **219** to the front drive train **241f** that includes a longitudinal gear train **251** connected to the right output shaft **219**, a front final reduction gear mechanism **253** of a planetary type arranged coaxial to the transmission output shaft **271** and connected to the gear train **251**, and a front differential gear set **255** of a bevel gear type connected between the front final gear **253** and a pair of front axles **265**, **267** of which a left one **265** extends through the transmission output shaft **271**.

The center differential **203** distributes the input drive torque in a differential manner, allowing for a difference developed between drive resistances of the left and right output shafts **213**, **215**.

The transverse transfer mechanism **243** comprises a bevel gear **245** fixed on the left output shaft **217** of the center differential **205**. The longitudinal transfer mechanism **249** comprises a bevel pinion **247** meshing with the bevel gear **245**, turning a torque transmitting direction at a right angle.

The gear train **251** comprises a drive gear **257** fixed on the right output shaft **219** of the center differential **203**, an idler gear **259** meshing with the drive gear **257**, and a driven gear **261** meshing with the idler gear **259**. The driven gear **261** is arranged coaxial to the output gear **209** of the transmission, and is coaxially connected at a right end thereof to a sun gear **263** as an input member of the front final reduction gear **253**. This final gear **253** as well as the front differential **255** may be identical to the previous embodiments. The left front axle **265** is provided through respective shaft parts of the driven gear **261** of the front final gear **251** and the output gear **209** of the transmission.

Branched torque to the rear transfer train **201** is a fraction of the drive torque transmitted to the center differential **203**, without a speed reduction and an associated torque increment that otherwise might have been effected at the front final gear **253**. The branched torque have smaller loads imposed on associated components such as the transverse and longitudinal transfer mechanisms **243**, **249** on the way of power transference to the rear drive train.

It therefore becomes possible to make the components comprising the rear transfer train **201** as well as the rear drive train in its entirety, lighter in weight and smaller in size.

Moreover, the front drive train **241f** is aligned with the transversely extending axles **265**, **267** and disposed near a vehicle centerline, permitting an optimized transverse location of the center of gravity of the rear transfer train **201**.

Further, as the rear transfer train **201** is enclosed within the left and central sections of the transfer housing **3** and the front drive train **241f** is enclosed within a right section thereof, these major component assemblies can adapt themselves well to unit construction, providing a high degree of drive train component interchangeability and an enhanced design commonality between two-wheel drive and four-wheel drive power trains.

While preferred embodiments of the present invention have been described using specific terms, such description is for illustrative purposes, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.

What is claimed is:

1. A power train for a vehicle with an engine and front and rear drive wheels, the power train comprising:

- a first power train adapted to drive front drive wheels, the first power train including:
 - a front transmission connected to the engine, the transmission having a hollow torque output shaft extending in a transverse direction of the vehicle;
 - a front reduction gear connected to the hollow torque output shaft of the transmission;
 - a front differential gear set connected to the front reduction gear; and
 - axles of the front wheels connected to the front differential gear set, one of the axles extending through the hollow torque output shaft of the transmission; and
- a second power train adapted to drive the rear drive wheels, the second power train including:
 - a power transfer train branched from the first power train between the hollow torque output shaft of the transmission and the front reduction gear;
 - a rear reduction gear connected to the power transfer train; and
 - a rear differential gear set connected between the rear reduction gear and the rear drive wheels.

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