United States Patent	12391330
Kind Code	B2
Date of Patent	August 19, 2025
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Wheel support device

Abstract

A wheel support device includes: a planetary gear mechanism including a first rotating element rotatable about a rotation center axis, a second rotating element rotatable about the rotation center axis and configured to rotate in a reverse direction of the first rotating element, and a reaction force element configured to generate a reaction force against inputs from the first rotating element and the second rotating element; a first arm member including a first base end portion coupled to the first rotating element and a first tip end portion rotatably supporting a first wheel of a vehicle, and configured to rotate integrally with the first rotating element about the rotation center axis; and a second arm member including a second base end portion coupled to the second rotating element and a second tip end portion rotatably supporting a second wheel of the vehicle, and configured to rotate integrally with the second rotating element about the rotation center axis.

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Appl. No.: **18/758736**

Filed: **June 28, 2024**

Prior Publication Data

Document Identifier	Publication Date
US 20250100646 A1	Mar. 27, 2025

Foreign Application Priority Data

JP	2023-163614	Sep. 26, 2023

Publication Classification

Int. Cl.: **B62K15/00** (20060101); **B62K5/02** (20130101); **F03G1/08** (20060101)

U.S. Cl.:

CPC **B62K15/008** (20130101); **F03G1/08** (20130101); B62K5/02 (20130101)

Field of Classification Search

CPC: F16H (3/60); B62K (15/006); B62K (15/008)

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This application is based on and claims priority under 35 U.S.C. § 119 to Japanese Patent Application 2023-163614, filed on Sep. 26, 2023, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

(2) This disclosure relates to a wheel support device.

BACKGROUND DISCUSSION

(3) In the related art, there is a wheel support device that causes a pair of wheels to move in reverse directions by causing a pair of arm members connected to a pair of left and right wheels of a vehicle to rotate in the reverse directions. For example, there is known a wheel support device that causes a pair of wheels to move in the reverse directions by causing a pair of arm members connected to a pair of left and right wheels of a vehicle to rotate in reverse directions using a string-shaped member (for example, see WO2010/092846 (Reference 1)).

(4) However, in the above related art, since a rotation center axis for causing the string-shaped member to move, that is, a rotation center axis of a mechanism for causing a pair of arm members to rotate in the reverse directions is different from a rotation center axis of the arm member, there is

a problem that a size of the wheel support device is increased.
(5) A need thus exists for a wheel support device which is not susceptible to the drawback mentioned above.

SUMMARY
(6) According to an aspect of this disclosure, a wheel support device includes: a planetary gear mechanism including a first rotating element rotatable about a rotation center axis, a second rotating element rotatable about the rotation center axis and configured to rotate in a reverse direction of the first rotating element, and a reaction force element configured to generate a reaction force against inputs from the first rotating element and the second rotating element; a first arm member including a first base end portion coupled to the first rotating element and a first tip end portion rotatably supporting a first wheel of a vehicle, and configured to rotate integrally with the first rotating element about the rotation center axis; and a second arm member including a second base end portion coupled to the second rotating element and a second tip end portion rotatably supporting a second wheel of the vehicle, and configured to rotate integrally with the second rotating element about the rotation center axis.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:
(2) FIG. **1** is an exemplary and schematic side view showing a schematic configuration of a vehicle according to a first embodiment, and is a view showing a developed state;
(3) FIG. **2** is an exemplary and schematic side view showing the schematic configuration of the vehicle according to the first embodiment, and is a view showing a folded state;
(4) FIG. **3** is an exemplary and schematic side view showing a detailed configuration of the vehicle according to the first embodiment;
(5) FIG. **4** is an exemplary and schematic cross-sectional view showing a drive system of the vehicle according to the first embodiment;
(6) FIG. **5** is an exemplary and schematic cross-sectional view showing a wheel support device of the vehicle according to the first embodiment;
(7) FIG. **6** is a cross-sectional view taken along a line VI-VI in FIG. **5**;
(8) FIG. **7** is an exemplary and schematic cross-sectional view showing a wheel support device according to a second embodiment;
(9) FIG. **8** is an exemplary and schematic cross-sectional view showing a wheel support device according to a third embodiment;
(10) FIG. **9** is an exemplary and schematic cross-sectional view showing a wheel support device according to a fourth embodiment;
(11) FIG. **10** is an exemplary and schematic cross-sectional view showing a wheel support device according to a fifth embodiment;
(12) FIG. **11** is an exemplary and schematic cross-sectional view showing a wheel support device according to a sixth embodiment; and
(13) FIG. **12** is an exemplary and schematic cross-sectional view showing the wheel support device according to the sixth embodiment.

DETAILED DESCRIPTION
(14) Hereinafter, embodiments and modifications disclosed here will be described with reference to the drawings. Configurations of the embodiments and modifications described below, as well as operational effects brought about by the configurations, are merely examples, and are not limited to

the following description.
(15) The drawings are schematic, and dimensional relationships of elements, ratios of elements, and the like may be different from actual ones. In addition, the drawings also include portions having different dimensional relationships and ratios from each other. In addition, in the present specification, an initial number is used only for distinguishing parts, members, portions, positions, directions, and the like, and does not indicate an order or priority.

First Embodiment

(16) FIG. **1** is an exemplary and schematic side view showing a schematic configuration of a vehicle **1** according to a first embodiment, and is a view showing a developed state. FIG. **2** is an exemplary and schematic side view showing the schematic configuration of the vehicle **1** according to the first embodiment, and is a view showing a folded state.
(17) The vehicle **1** shown in FIGS. **1** and **2** has a configuration capable of manual travelling, electrically assisted travelling, or completely electrical-driven travelling. The vehicle **1** is an example of an electrically assisted tricycle.
(18) The vehicle **1** is deformable into the developed state shown in FIG. **1** and the folded state shown in FIG. **2**. That is, the vehicle **1** is a foldable vehicle. The vehicle **1** can travel on a ground G (road surface) in the developed state. In the vehicle **1**, in the folded state of the vehicle **1**, at least a part of a front wheel **3**F and at least a part of rear wheels **3**R are aligned in an axial direction of a first rotation center axis Ax**1** to be described later.
(19) The vehicle **1** will be described in detail. FIG. **3** is an exemplary and schematic side view showing a detailed configuration of the vehicle **1** according to the first embodiment. FIG. **4** is an exemplary and schematic cross-sectional view showing a drive system of the vehicle **1** according to the first embodiment. As shown in FIGS. **3** and **4**, the vehicle **1** includes a frame **2**, a plurality of (for example, three) wheels **3**, a drive mechanism **4**, a steering portion **5**, and a seat portion **6**.
(20) The three wheels **3** are one front wheel **3**F and two rear wheels **3**R (**3**RL, **3**RR). The three wheels **3** are rotatably supported by the frame **2**. Specifically, the front wheel **3**F is supported by the frame **2** via the steering portion **5**. The two rear wheels **3**R are supported by the frame **2** via arm members **81**R and **81**L, respectively. The two rear wheels **3**RL and **3**RR are provided at an interval in a left-right direction of the vehicle **1**. The two rear wheels **3**RL and **3**RR are fixed to two shafts **53**, and rotate integrally with the two shafts **53** about the first rotation center axis Ax**1**. The left-right direction of the vehicle **1** is also referred to as a width direction (vehicle width direction). The two rear wheels **3**R are examples of two wheels.
(21) The drive mechanism **4** rotationally drives the two rear wheels **3**RL and **3**RR. The drive mechanism **4** includes left and right two pedals **11**, two pedal arm members **12**, a drive gear **13** (front sprocket), a driven gear **14** (rear sprocket), and a chain **15**. The chain **15** is stretched between the drive gear **13** and the driven gear **14**. The drive gear **13** and the driven gear **14** can transmit power by the chain **15**, and a motor **17** is connected to the driven gear **14** via a transmission unit **18**. The drive gear **13** is an example of a drive portion, the driven gear **14** is an example of a driven portion, and the chain **15** is an example of a connecting member. The drive portion, the driven portion, and the connecting member are not limited to those described above. For example, the drive portion and the driven portion may be both pulleys, and the connecting member may be a belt.
(22) The two pedals **11** are provided so as to be rotatable about a support portion rotation center axis Ax**2**. Specifically, the two pedals **11** are connected to the drive gear **13** via the two pedal arm members **12**. The drive gear **13** is supported by the frame **2** (base frame **2***a*) so as to be rotatable about the support portion rotation center axis Ax**2**. Specifically, the drive gear **13** is supported by the frame **2** (base frame **2***a*) via a rotation support portion **71** to be described later. The pedals **11** cause the drive gear **13** to rotate by being rotated about the support portion rotation center axis Ax**2** by human power of a rider. The support portion rotation center axis Ax**2** is along the first rotation center axis Ax**1**.

(23) The driven gear **14** is coupled to the rear wheel **3**R via the shaft **53**, and rotates integrally with the rear wheel **3**R about the first rotation center axis Ax**1**. Specifically, the driven gear **14** is connected to the shafts **53** via a one-way clutch **52**. The one-way clutch **52** transmits a rotational force of the drive gear **13** rotating in a first rotational direction, which is a rotational direction of the drive gear **13** when the vehicle **1** moves forward, to the rear wheel **3**R via the shaft **53**. On the other hand, the one-way clutch **52** interrupts transmission of a rotational force of the rear wheel **3**R to the driven gear **14**. Specifically, when the drive gear **13** and the driven gear **14** rotate in the first rotational direction, the one-way clutch **52** connects the driven gear **14** and the shaft **53** to cause the driven gear **14** and the shaft **53** to integrally rotate. When the driven gear **14** rotates in a direction opposite to the first rotational direction relative to the shaft **53**, the one-way clutch **52** does not connect the driven gear **14** and the shaft **53**, and causes the driven gear **14** and the shaft **53** (rear wheel **3**R) to rotate relative to each other. That is, in a case where a rotation speed of the shaft **53** is greater than a rotation speed of the driven gear **14** when the vehicle **1** moves forward, the one-way clutch **52** releases the connection between the shaft **53** and the driven gear **14**.
(24) In the above configuration, a rotational motion of the pedal **11** is converted into a rotational motion of the rear wheels **3**R via the drive gear **13**, the chain **15**, and the driven gear **14**. The two pedals **11**, the two pedal arm members **12**, and a shaft **73** constitute a crank pedal **11**A. That is, the crank pedal **11**A is provided to be rotatable about the support portion rotation center axis Ax**2**, and causes the rear wheels **3**R to rotate about the first rotation center axis Ax**1** via the chain **15**. The crank pedal **11**A is an example of a manual drive device.
(25) The motor **17** applies a rotational force (assist force) in accordance with an operation force (pressing force) acting on the pedals **11** to the driven gear **14** via the transmission unit **18**. Accordingly, when the vehicle **1** travels, the rear wheels **3**RL and **3**RR are rotationally driven by the operation force (pressing force) acting on the pedals **11** and the force transmitted from the motor **17**. The motor **17** is rotated by electric power supplied from a battery (not shown).
(26) In addition, the drive mechanism **4** has a braking function. The drive mechanism **4** generates a braking force by a brake device by operating a brake operation member. At this time, the drive mechanism **4** can also generate the braking force by a regenerative operation of the motor **17**.
(27) The vehicle **1** can switch among a manual travel mode in which the vehicle **1** travels only by an operation of the drive mechanism **4**, an assist travel mode driven by the motor **17**, and an electric travel mode in which the vehicle **1** travels only by the driving of the motor **17** by causing a clutch to interpose between the motor **17** and the transmission unit **18**, or the like. The vehicle **1** may travel only by manual drive without the motor **17** and the transmission unit **18**.
(28) As shown in FIG. **3**, the steering portion **5** includes a handle **31** and a front support portion **32** coupled to the handle **31**. The front support portion **32** rotatably supports the front wheel **3**F. The steering portion **5** is rotatably connected to the frame **2** via a connecting portion **33**.
(29) The frame **2** includes a base frame **2***a*, an upper member **2***b*, a rear connecting member **2***c*, and a front connecting member **2***d*. The base frame **2***a* extends in a front-rear direction of the vehicle **1**. The base frame **2***a* has a first front end portion **2***aa* and a first rear end portion **2***ab*. The upper member **2***b* extends in the front-rear direction of the vehicle **1** and is positioned above the base frame **2***a*. Specifically, the upper member **2***b* is inclined with respect to the front-rear direction of the vehicle **1** so as to be directed downward toward a rear side. The base frame **2***a* and the upper member **2***b* are connected via the rear connecting member **2***c* and the front connecting member **2***d*. The base frame **2***a*, the upper member **2***b*, the rear connecting member **2***c*, and the front connecting member **2***d* are rotatably connected to one another. The upper member **2***b* is expandable and contractible. The upper member **2***b* has a lock mechanism that locks expansion and contraction.
(30) The seat portion **6** is supported by the rear connecting member **2***c* in a manner capable of adjusting a height.
(31) The vehicle **1** according to the present embodiment includes a front portion Fr, a rear portion Rr, and the rotation support portion **71**.

(32) The front portion Fr includes the front support portion **32**, the front wheel **3**F, and the handle **31**. The front support portion **32** is coupled to the first front end portion **2***aa* of the base frame **2***a*. The front support portion **32** rotatably supports the front wheel **3**F. The front support portion **32** supports the handle **31**.
(33) The front portion Fr is connected to the first front end portion **2***aa* of the base frame **2***a* so as to be rotatable about a front portion rotation center axis Ax**4** along the first rotation center axis Ax**1**. The front portion Fr is rotatable about the front portion rotation center axis Ax**4** in a forward-rotation direction which is a rotational direction of the rear wheels **3**R when the vehicle **1** moves forward from the developed state.
(34) The rear portion Rr includes a rear support portion **61** and the rear wheels **3**R. The rear support portion **61** includes a second front end portion **61***a* and a second rear end portion **61***b*. The rear portion Rr extends rearward in the front-rear direction of the vehicle **1** from the first rear end portion **2***ab* of the base frame **2***a* in the developed state.
(35) The rear wheel **3**R is supported by the second rear end portion **61***b* of the rear support portion **61** so as to be rotatable about the first rotation center axis Ax**1** along the width direction of the vehicle **1**.
(36) The rotation support portion **71** connects the rear portion Rr to the first rear end portion **2***ab* of the base frame **2***a* so as to be rotatable about the support portion rotation center axis Ax**2** along the first rotation center axis Ax**1**. The rotation support portion **71** generates a reaction force against a load from the rear portion Rr in the developed state. The rotation support portion **71** is capable of moving the rear wheels **3**R from a position behind the first rear end portion **2***ab* in the developed state in the front-rear direction to a position of the folded state on a first front end portion **2***aa* side of the base frame **2***a* with respect to the first rear end portion **2***ab* of the base frame **2***a*. Details of the rotation support portion **71** will be described later.
(37) The seat portion **6** is connected to the first rear end portion **2***ab* of the base frame **2***a* so as to be rotatable about a seat portion rotation center axis Ax**3** along the first rotation center axis Ax**1**. In the developed state, the seat portion **6** extends from the base frame **2***a* obliquely upward to the rear side of the vehicle **1**. The seat portion **6** is rotatable about the seat portion rotation center axis Ax**3** in the forward-rotation direction which is the rotational direction of the rear wheels **3**R when the vehicle **1** moves forward from the developed state.
(38) In addition, the front portion Fr is connected to the first front end portion **2***aa* of the base frame **2***a* so as to be rotatable about the front portion rotation center axis Ax**4** along the first rotation center axis Ax**1**. The front portion Fr is rotatable about the front portion rotation center axis Ax**4** in the forward-rotation direction which is the rotational direction of the rear wheels **3**R when the vehicle **1** moves forward from the developed state.
(39) The vehicle **1** includes an interlocking mechanism **81**. The interlocking mechanism **81** causes the rotation of the seat portion **6** about the seat portion rotation center axis Ax**3** and the rotation of the front portion Fr about the front portion rotation center axis Ax**4** to be interlocked. The interlocking mechanism **81** is a link mechanism including the base frame **2***a*, the upper member **2***b*, the rear connecting member **2***c*, and the front connecting member **2***d*.
(40) As shown in FIG. **4**, the rear portion Rr includes the arm member **81**R and the arm member **81**L. The arm member **81**R and the arm member **81**L are separated from each other in an axial direction of the support portion rotation center axis Ax**2**, that is, an axial direction of the shaft **73**. The arm member **81**R includes a base end portion **81**Ra supported by the rotation support portion **71** and a tip end portion **81**Rb rotatably supporting the rear wheel **3**RR which is a first rear wheel. The arm member **81**L includes a base end portion **81**La supported by the rotation support portion **71** and a tip end portion **81**Lb rotatably supporting the rear wheel **3**RL which is a second rear wheel. The arm member **81**R and the arm member **81**L are rotatable about the support portion rotation center axis Ax**2**.
(41) The rotation support portion **71**, the arm member **81**R, and the arm member **81**L constitute a

wheel support device **100**. The wheel support device **100** functions as a suspension.
(42) FIG. **5** is an exemplary and schematic cross-sectional view showing the wheel support device of the vehicle according to the first embodiment. FIG. **6** is a cross-sectional view taken along a line VI-VI in FIG. **5**. As shown in FIGS. **5** and **6**, the rotation support portion **71** includes a planetary gear mechanism **101** capable of causing the arm member **81**R and the arm member **81**L to rotate in reverse directions to each other, rotating members **102**L and **102**R, a reaction force mechanism **103**, and a case **104**.
(43) The case **104** is fixed to the base frame **2***a*. The case **104** accommodates the planetary gear mechanism **101** and the reaction force mechanism **103**.
(44) The rotating members **102**L and **102**R are rotatable about the support portion rotation center axis Ax**2**. The rotating members **102**L and **102**R are disposed side by side in the axial direction of the support portion rotation center axis Ax**2**. The rotating members **102**L and **102**R are, for example, shafts. The base end portion **81**La of the arm member **81**L is fixed to the rotating member **102**L, and the rotating member **102**L and the arm member **81**L integrally rotate about the support portion rotation center axis Ax**2**. The base end portion **81**Ra of the arm member **81**R is fixed to the rotating member **102**R, and the rotating member **102**R and the arm member **81**R integrally rotate about the support portion rotation center axis Ax**2**.
(45) The planetary gear mechanism **101** is, for example, a double-pinion gear type planetary gear mechanism. Specifically, the planetary gear mechanism **101** includes a sun gear **111**, a planetary carrier **112**, a plurality of inner pinion gears **113**, a plurality of outer pinion gears **114**, and a ring gear **115**.
(46) The sun gear **111** is provided integrally with the rotating member **102**L, and rotates integrally with the rotating member **102**L. That is, the sun gear **111** is coupled to the arm member **81**L via the rotating member **102**L, and rotates integrally with the arm member **81**L.
(47) The planetary carrier **112** is provided integrally with the rotating member **102**R, and rotates integrally with the rotating member **102**R. That is, the planetary carrier **112** is coupled to the arm member **81**R via the rotating member **102**R, and rotates integrally with the arm member **81**R.
(48) The plurality of inner pinion gears **113** and the plurality of outer pinion gears **114** are rotatably supported by the planetary carrier **112**, and rotate integrally with the planetary carrier **112**. The inner pinion gears **113** mesh with the sun gear **111**. The outer pinion gears **114** mesh with the inner pinion gears **113** and the ring gear **115**.
(49) In the planetary gear mechanism **101** having the above configuration, the sun gear **111** and the planetary carrier **112** are rotatable in reverse directions. That is, the planetary gear mechanism **101** causes the arm member **81**R and the arm member **81**L to rotate in the reverse directions (opposite directions) to each other. For example, when one of the arm member **81**R and the arm member **81**L is rotated in one direction about the support portion rotation center axis Ax**2** by an external force, the planetary gear mechanism **101** causes the other one of the arm member **81**R and the arm member **81**L to rotate in the other direction about the support portion rotation center axis Ax**2**. The planetary gear mechanism **101** supports the arm members **81**L and **81**R such that the arm members **81**L and **81**R are rotatable by 180 degrees or more about the support portion rotation center axis Ax**2**. The planetary gear mechanism **101** is also referred to as a reversing mechanism. The arm member **81**L is an example of a first arm member, and the arm member **81**R is an example of a second arm member. The sun gear **111** is an example of a first rotating element, the planetary carrier **112** is an example of a second rotating element, and the ring gear **115** is an example of a reaction force element.
(50) The reaction force mechanism **103** includes a motion conversion mechanism **121** and an elastic member **122**. The motion conversion mechanism **121** includes a rotating member **123** and a linear motion member **124**. The rotating member **123** is provided integrally with the ring gear **115**, and rotates integrally with the ring gear **115**. The rotating member **123** has a cylindrical shape about the support portion rotation center axis Ax**2**, and has a male screw (helical spline) formed on

an outer peripheral portion thereof. The linear motion member **124** has a cylindrical shape about the support portion rotation center axis Ax**2**, and is supported by the case **104** so as to linearly move in the axial direction of the support portion rotation center axis Ax**2**. In addition, a female screw (helical spline) that meshes with the male screw of the rotating member **123** is formed on an inner peripheral portion of the linear motion member **124**. The elastic member **122** is interposed between the linear motion member **124** and a wall **104***a* of the case **104**. The elastic member **122** is a coil spring.

(51) In the reaction force mechanism **103** having the above configuration, a rotational motion of the ring gear **115** is converted into a linear motion of the linear motion member **124** by the rotating member **123** and the linear motion member **124**. When the linear motion member **124** moves in a direction approaching the wall **104***a* of the case **104**, the elastic member **122** sandwiched between the linear motion member **124** and the wall **104***a* is compressed to generate a reaction force (elastic force). The reaction force mechanism **103** generates the reaction force against the load from the rear wheels **3**R in the developed state. Specifically, when the ring gear **115** is rotated by the two arm members **81**R and **81**L rotating in a direction in which the two tip end portions **81**Rb and **81**Lb of the arm members **81**R and **81**L and the two rear wheels **3**R are directed upward in an upper-lower direction of the vehicle **1**, the reaction force mechanism **103** generates the reaction force by being compressed by the linear motion member **124** that linearly moves in accordance with the rotation of the ring gear **115**. This reaction force is transmitted to the arm members **81**R and **81**L.

(52) A preload is set for the elastic member **122**. That is, the elastic member **122** is provided in a compressed state to which the load is applied in advance. When a rotational torque input to the ring gear **115** (reaction force element) is less than a threshold, the linear motion member **124** is stopped by the elastic force of the elastic member **122**. Accordingly, for example, the state shown in FIG. **3** is maintained. When the rotational torque input to the ring gear **115** is equal to or greater than the threshold, the linear motion member **124** linearly moves against the elastic force of the elastic member **122**. The preload may not be set for the elastic member **122**.

(53) The wheel support device **100** is capable of moving the rear wheels **3**R from the position (FIG. **1** and FIG. **3**) behind the first rear end portion **2***ab* in the developed state in the front-rear direction to the position (FIG. **2**) of the folded state on the first front end portion **2***aa* side of the base frame **2***a* with respect to the first rear end portion **2***ab* of the base frame **2***a*. Specifically, the wheel support device **100** can move the left and right rear wheels **3**R to the position of the folded state by causing the arm member **81**R and the arm member **81**L to rotate in the reverse directions. The planetary gear mechanism **101** is also referred to as a lean mechanism.

(54) In the vehicle **1** having the above configuration, in the developed state, the frame **2** of each part cannot be deformed by a lock pin P, and the frame **2** can be deformed by removing the lock pin P, and thus the vehicle **1** can be folded.

(55) As described above, in the present embodiment, the wheel support device **100** includes the planetary gear mechanism **101**, the arm member **81**L (first arm member), and the arm member **81**R (second arm member). The planetary gear mechanism **101** includes the sun gear **111** (first rotating element), the planetary carrier **112** (second rotating element), and the ring gear **115** (reaction force element). The sun gear **111** is rotatable about the support portion rotation center axis Ax**2** (rotation center axis). The planetary carrier **112** is rotatable about the support portion rotation center axis Ax**2** and rotates in the reverse direction of the sun gear **111**. The ring gear **115** generates a reaction force against inputs from the sun gear **111** and the planetary carrier **112**. The arm member **81**L includes the base end portion **81**La (first base end portion) coupled to the sun gear **111**, and the tip end portion **81**Lb (first tip end portion) rotatably supporting the rear wheel **3**RL (first wheel) of the vehicle **1**, and rotates integrally with the sun gear **111** about the support portion rotation center axis Ax**2**. The arm member **81**R includes the base end portion **81**Ra (second base end portion) coupled to the planetary carrier **112**, and the tip end portion **81**Rb (second tip end portion) rotatably supporting the rear wheel **3**RR (second wheel) of the vehicle **1**, and rotates integrally with the

planetary carrier **112** about the support portion rotation center axis Ax**2**.
(56) According to such a configuration, since the support portion rotation center axis Ax**2** of the planetary gear mechanism **101**, which is a mechanism for causing the arm member **81**L and the arm member **81**R to rotate in the reverse directions, and the support portion rotation center axis Ax**2** of the arm member **81**L and the arm member **81**R are the same, it is possible to prevent an increase in a size of the wheel support device **100**.
(57) The wheel support device **100** includes the reaction force mechanism **103**. The ring gear **115** rotates about the support portion rotation center axis Ax**2** in conjunction with the rotation of the planetary carrier **112** and the sun gear **111**. The reaction force mechanism **103** includes the linear motion member **124** that linearly moves in the axial direction of the support portion rotation center axis Ax**2** in accordance with the rotation of the ring gear **115**, and the elastic member **122** that generates the reaction force in accordance with the linear motion of the linear motion member **124**.
(58) According to this configuration, a load (impact) input to the wheel support device **100** can be absorbed by the elastic force of the elastic member **122**.
(59) The first rotating element is the sun gear **111**, and the second rotating element is the planetary carrier **112**.
(60) According to such a configuration, for example, a length of the planetary gear mechanism **101**, which is the reversing mechanism, in the axial direction of the support portion rotation center axis Ax**2** is easily shortened as compared with a case where a bevel gear reversing mechanism is adopted as the reversing mechanism.
(61) Further, the reaction force mechanism **103** has a tubular shape about the support portion rotation center axis Ax**2**, and includes the rotating member **123** (tubular member) that rotates integrally with the ring gear **115**. The linear motion member **124** is connected to the ring gear **115** via the rotating member **123**, and linearly moves in the axial direction of the support portion rotation center axis Ax**2** in accordance with the rotation of the rotating member **123** and the ring gear **115**.
(62) According to such a configuration, the reaction force can be generated by a relatively simple configuration, and the size of the wheel support device **100** can be reduced.
(63) In addition, the preload is set for the elastic member **122**. When the rotational torque input to the ring gear **115** is less than the threshold, the linear motion member **124** is stopped by the elastic force of the elastic member **122**, and when the rotational torque input to the ring gear **115** is equal to or greater than the threshold, the linear motion member **124** linearly moves.
(64) According to such a configuration, an expansion and contraction length (stroke) of the elastic member **122** is likely to be shortened, and a length of the wheel support device **100** in the axial direction of the support portion rotation center axis Ax**2** is likely to be shortened.

Second Embodiment

(65) FIG. **7** is an exemplary and schematic cross-sectional view showing a wheel support device according to a second embodiment. The present embodiment is different from the first embodiment mainly in the configuration of the planetary gear mechanism **101** and the configuration of the reaction force mechanism **103**.
(66) The planetary gear mechanism **101** according to the present embodiment is a 2KH-type planetary gear mechanism, and includes a first sun gear **111**A (first rotating element), a second sun gear **111**B (reaction force element), the planetary carrier **112** (second rotating element), a plurality of pinion gears **116** (hereinafter also referred to as first pinion gears **116**A), and a second pinion gear **116**B that rotates integrally with the first pinion gears **116**A. The first sun gear **111**A is provided in the rotating member **102**R, and rotates integrally with the rotating member **102**R. The planetary carrier **112** is provided in the rotating member **102**L, and rotates integrally with the rotating member **102**L. The first pinion gears **116**A mesh with the first sun gear **111**A. The second pinion gear **116**B meshes with the second sun gear **111**B.
(67) The motion conversion mechanism **121** of the reaction force mechanism **103** according to the

present embodiment includes the rotating member **123** and the linear motion member **124**.
(68) The rotating member **123** is provided integrally with the second sun gear **111**B, and rotates integrally with the second sun gear **111**B. The rotating member **123** has the cylindrical shape about the support portion rotation center axis Ax**2**, and has the male screw (helical spline) formed on the outer peripheral portion thereof. The linear motion member **124** has the cylindrical shape about the support portion rotation center axis Ax**2**, and is supported by the case **104** so as to linearly move in the axial direction of the support portion rotation center axis Ax**2**. In addition, the female screw (helical spline) that meshes with the male screw of the rotating member **123** is formed the inner peripheral portion of the linear motion member **124**. The elastic member **122** is interposed between the linear motion member **124** and the wall **104***a* of the case **104**. The elastic member **122** is the coil spring.
(69) In the reaction force mechanism **103** having the above configuration, a rotational motion of the second sun gear **111**B is converted into the linear motion of the linear motion member **124** by the rotating member **123** and the linear motion member **124**. When the linear motion member **124** moves in the direction approaching the wall **104***a* of the case **104**, the elastic member **122** sandwiched between the linear motion member **124** and the wall **104***a* is compressed to generate the reaction force (elastic force). The reaction force mechanism **103** generates the reaction force against the load from the rear wheels **3**R in the developed state.
(70) The preload is set for the elastic member **122**. That is, the elastic member **122** is provided in the compressed state to which the load is applied in advance. When a rotational torque input to the second sun gear **111**B (reaction force element) is less than the threshold, the linear motion member **124** is stopped by the elastic force of the elastic member **122**, and when the rotational torque input to the second sun gear **111**B is equal to or greater than the threshold, the linear motion member **124** linearly moves against the elastic force of the elastic member **122**. The preload may not be set for the elastic member **122**.
Third Embodiment
(71) FIG. **8** is an exemplary and schematic cross-sectional view showing a wheel support device according to a third embodiment. The present embodiment is different from the first embodiment mainly in that the reaction force mechanism **103** includes a preload adjustment mechanism **131**.
(72) The preload adjustment mechanism **131** includes a support member **132** and a linear motion member **133**. The support member **132** is fixed to the case **104**. The support member **132** has a cylindrical shape about the support portion rotation center axis Ax**2**, and has a male screw (helical spline) formed on an outer peripheral portion thereof. The linear motion member **133** has a cylindrical shape about the support portion rotation center axis Ax**2**, and is supported by the case **104** so as to linearly move in the axial direction of the support portion rotation center axis Ax**2**. In addition, a female screw (helical spline) that meshes with the male screw of the support member **132** is formed on an inner peripheral portion of the linear motion member **133**. The elastic member **122** is interposed between the linear motion member **124** and the linear motion member **133**.
(73) In the above configuration, a compression amount, that is, the preload of the elastic member **122** can be adjusted by causing the linear motion member **133** to move in the axial direction to change a position of the linear motion member **133**.
Fourth Embodiment
(74) FIG. **9** is an exemplary and schematic cross-sectional view showing a wheel support device according to a fourth embodiment. The present embodiment is different from the first embodiment mainly in that a pair of arm members **81**L and **81**R are supported by a single shaft **141**, and the shaft **141** penetrates the rotation support portion **71**.
(75) The rotating members **102**L and **102**R according to the present embodiment have cylindrical shapes about the support portion rotation center axis Ax**2**, the shaft **141** is inserted therein, and the rotating members **102**L and **102**R are provided to be rotatable with respect to the shaft **141**. The rotating members **102**L and **102**R are disposed side by side in the axial direction of the support

portion rotation center axis Ax**2**. The rotating members **102**L and **102**R are, for example, shafts. The tip end portion **81**Lb of the arm member **81**L is fixed to the rotating member **102**L, and the rotating member **102**L and the arm member **81**L integrally rotate about the support portion rotation center axis Ax**2**. The tip end portion **81**Rb of the arm member **81**R is fixed to the rotating member **102**R, and the rotating member **102**R and the arm member **81**R integrally rotate about the support portion rotation center axis Ax**2**.

Fifth Embodiment

(76) FIG. **10** is an exemplary and schematic cross-sectional view showing a wheel support device according to a fifth embodiment. The present embodiment is mainly different from the fourth embodiment in the motion conversion mechanism **121** and the elastic member **122**.

(77) The motion conversion mechanism **121** according to the present embodiment includes a support portion **151** and the ring gear **115**. The support portion **151** is a female screw portion (helical spline) provided in the case **104**. A male screw portion (helical spline) that meshes with the support portion **151** is provided on an outer peripheral portion of the ring gear **115**. A pressing member **152** is interposed between the ring gear **115** and the elastic member **122**. The elastic member **122** is made of, for example, rubber, and the preload is set. In the above configuration, when the ring gear **115** rotates in one direction, the ring gear **115** is guided by the support portion **151** and moves to one side in the axial direction, and presses the elastic member **122** via the pressing member **152** and causes the elastic member **122** to be compressed. The ring gear **115** is an example of a linear motion member.

Sixth Embodiment

(78) FIG. **11** is an exemplary and schematic cross-sectional view showing a wheel support device according to a sixth embodiment. FIG. **12** is an exemplary and schematic cross-sectional view showing the wheel support device according to the sixth embodiment. The present embodiment is different from the fifth embodiment in the motion conversion mechanism **121**. In the present embodiment, the linear motion member **124** meshes with the male screw portion on the outer peripheral portion of the ring gear **115**. The linear motion member **124** is supported by the support portion **151** via an interposing member **161**. The support portion **151** is provided on an inner peripheral portion of the case **104**. The support portion **151** is formed in a concave shape and extends in the axial direction. In the above configuration, when the ring gear **115** rotates in one direction, the linear motion member **124** is guided by the support portion **151** via the interposing member **161** and moves to one side in the axial direction, and presses the elastic member **122** via the pressing member **152** and causes the elastic member **122** to be compressed. In the present embodiment, no female screw portion is provided in the support portion **151**.

(79) According to an aspect of this disclosure, a wheel support device includes: a planetary gear mechanism including a first rotating element rotatable about a rotation center axis, a second rotating element rotatable about the rotation center axis and configured to rotate in a reverse direction of the first rotating element, and a reaction force element configured to generate a reaction force against inputs from the first rotating element and the second rotating element; a first arm member including a first base end portion coupled to the first rotating element and a first tip end portion rotatably supporting a first wheel of a vehicle, and configured to rotate integrally with the first rotating element about the rotation center axis; and a second arm member including a second base end portion coupled to the second rotating element and a second tip end portion rotatably supporting a second wheel of the vehicle, and configured to rotate integrally with the second rotating element about the rotation center axis.

(80) According to the wheel support device disclosed here, it is possible to prevent an increase in size of the wheel support device.

(81) The principles, preferred embodiment and mode of operation of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. Further, the

embodiments described herein are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others, and equivalents employed, without departing from the spirit of the present invention. Accordingly, it is expressly intended that all such variations, changes and equivalents which fall within the spirit and scope of the present invention as defined in the claims, be embraced thereby.

Claims

1. A wheel support device comprising: a planetary gear mechanism including a first rotating element rotatable about a rotation center axis, a second rotating element rotatable about the rotation center axis and configured to rotate in a reverse direction of the first rotating element, and a reaction force element configured to generate a reaction force against inputs from the first rotating element and the second rotating element; a first arm member including a first base end portion coupled to the first rotating element and a first tip end portion rotatably supporting a first wheel of a vehicle, and configured to rotate integrally with the first rotating element about the rotation center axis; and a second arm member including a second base end portion coupled to the second rotating element and a second tip end portion rotatably supporting a second wheel of the vehicle, and configured to rotate integrally with the second rotating element about the rotation center axis.
2. The wheel support device according to claim 1, further comprising: a reaction force mechanism, wherein the reaction force element rotates about the rotation center axis in conjunction with the rotation of the first rotating element and the second rotating element, and the reaction force mechanism includes a linear motion member configured to linearly move in an axial direction of the rotation center axis in accordance with the rotation of the reaction force element, and an elastic member configured to generate a reaction force in accordance with the linear motion of the linear motion member.
3. The wheel support device according to claim 2, wherein the reaction force mechanism has a tubular shape about the rotation center axis and includes a tubular member that rotates integrally with the reaction force element, and the linear motion member is connected to the reaction force element via the tubular member and linearly moves in the axial direction of the rotation center axis in accordance with the rotation of the tubular member and the reaction force element.
4. The wheel support device according to claim 2, wherein a preload is set for the elastic member, and when a rotational torque input to the reaction force element is less than a threshold, the linear motion member is stopped by an elastic force of the elastic member, and when the rotational torque input to the reaction force element is equal to or greater than the threshold, the linear motion member linearly moves.
5. The wheel support device according to claim 1, wherein the first rotating element is a sun gear, and the second rotating element is a planetary carrier.