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SUSPENSION APPARATUS

Abstract

A suspension apparatus and a suspension apparatus for a vehicle are provided. The suspension apparatus includes a drive unit installed inside a wheel, a first knuckle connected to the drive unit and configured to rotate around a first axis, a second knuckle connected to the first knuckle and configured to move along a second axis spaced apart from the first axis, a first suspension arm connected to the second knuckle and configured to support the second knuckle with respect to a vehicle body, and a limiting member connected to the first suspension arm and configured to limit rotation of the second knuckle around the second axis.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority from and the benefit under 35 USC § 119 of Korean Patent Application No. 10-2024-0025358 filed on Feb. 21, 2024, in the Korean Intellectual Property Office, the entire disclosure of which is hereby incorporated by reference for all purposes.

BACKGROUND

1. FIELD

[0002] Exemplary embodiments of the present disclosure relate to a suspension apparatus, and more particularly, to a vehicle suspension apparatus in which a steering axis and a suspension axis are separated from each other.

2. DESCRIPTION OF THE RELATED ART

[0003] In general, around the world, cars are changing from being a means of transportation to an extension of living space, and thus, purpose-built vehicles (PBVs) with an ample interior space are spotlighted. Such purpose-based vehicles have an expanded interior space by applying in-wheel motors that directly drive wheels by placing a drive motor inside each wheel, unlike a typical electric vehicle having a drive motor that is located in the place of an existing internal combustion engine.

[0004] However, when a space inside the wheel becomes narrower than before due to the in-wheel motor and a driving force and a braking force are applied to the wheel due to an increase in a kingpin offset, there is a problem in that a torque steer phenomenon occurs in which the wheel is arbitrarily steered.

[0005] The background art of the present disclosure is disclosed in Korean Patent Application Laid-Open No. 10-2019-0041855 (published on Apr. 23, 2019 and entitled “Steering System for In-Wheel Motor Vehicle”).

SUMMARY

[0006] This Summary is provided to introduce a selection of concepts in simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0007] Various embodiments are directed to providing a suspension apparatus that can improve the driving stability of a vehicle.

[0008] In a general aspect of the disclosure, a suspension apparatus includes: a drive unit installed inside a wheel; a first knuckle connected to the drive unit and configured to rotate around a first axis; a second knuckle connected to the first knuckle and configured to move along a second axis spaced apart from the first axis; a first suspension arm connected to the second knuckle and configured to support the second knuckle with respect to a vehicle body; and a limiting member connected to the first suspension arm and configured to limit rotation of the second knuckle around the second axis.

[0009] A distance between the second axis and the wheel may be greater than a distance between the first axis and the wheel.

[0010] The drive unit, the first knuckle, and the second knuckle may be sequentially disposed from the wheel toward the vehicle body.

[0011] The first suspension arm may include: a first arm body configured to extend from the vehicle body toward the second knuckle; a joint body connected to the second knuckle and comprising a first end and a second end; and a first joint connected to the first end and configured to rotatably support the first arm body.

[0012] The first end of the joint body may protrudes at one side of the second knuckle, wherein the

second end of the joint body may protrude at another side of the second knuckle.
[0013] The first end and the second end may be spaced apart from each other in a direction intersecting the second axis.
[0014] The second axis may be inclined with respect to a third axis extending vertically from a ground and a longitudinal direction of the vehicle body, wherein the first joint may have a spherical shape.
[0015] Both sides of the limiting member may be respectively connected to the vehicle body and the second end.
[0016] The limiting member may include: a limiting link spaced apart from the first arm body and configured to extend from the vehicle body toward the second knuckle; and a limiting joint connected to the second end and configured to rotatably support the limiting link with respect to the second end.
[0017] The limiting joint may include: an outer body connected to the limiting link; an inner body disposed inside the outer body and connected to the second end; and a stud connected to the inner body and configured to rotatably contact with the outer body.
[0018] The second axis may be inclined with respect to a third axis extending vertically from a ground and a longitudinal direction of the vehicle body, wherein the stud may have a spherical shape.
[0019] The limiting joint may further include a stopper disposed to surround the inner body and configured to restrict the stud from rotating about a direction parallel to the second axis.
[0020] A width of the stopper parallel to the second axis may be greater than a width of the stopper intersecting the second axis.
[0021] The suspension apparatus may further include a second suspension arm spaced apart from the first suspension arm and connected to the second knuckle.
[0022] The second knuckle may include a first connection part and a second connection part spaced apart from each other along the second axis, wherein the first suspension arm and the second suspension arm may be respectively connected to the first connection part and the second connection part.
[0023] In another general aspect of the disclosure, a suspension apparatus for a vehicle includes: a drive unit installed inside a wheel and configured to provide a driving force to rotate the wheel; a brake unit configured to provide a braking force to the wheel; a first knuckle connected to the drive unit and configured to rotate around a first axis; a second knuckle connected to the first knuckle and configured to move along a second axis spaced apart from the first axis; a first suspension arm connected to the second knuckle and configured to support the second knuckle with respect to a vehicle body; and a limiting member connected to the first suspension arm and configured to limit rotation of the second knuckle around the second axis.
[0024] The drive unit may include a motor.
[0025] The first knuckle, the second knuckle, the first suspension arm and the limiting member may be configured to counter an increase in torque steer due to an increase in a kingpin offset, in response to at least one of the driving force being applied by the drive unit, the braking force being applied by the brake unit, or a combination thereof.
[0026] A distance between the second axis and the wheel may be greater than a distance between the first axis and the wheel, wherein the drive unit, the first knuckle, and the second knuckle may be sequentially disposed from the wheel toward the vehicle body.
[0027] The first suspension arm may include: a first arm body configured to extend from the vehicle body toward the second knuckle; a joint body connected to the second knuckle and comprising a first end and a second end; and a first joint connected to the first end and configured to rotatably support the first arm body.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. **1** is a view schematically illustrating an installation state of a suspension apparatus in accordance with an embodiment of the present disclosure.

[0029] FIG. **2** is a perspective view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure.

[0030] FIG. **3** is a side view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure.

[0031] FIG. **4** is a front view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure.

[0032] FIG. **5** is an exploded perspective view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure.

[0033] FIG. **6** is an enlarged view schematically illustrating the configuration of a first suspension arm and a limiting member in accordance with an embodiment of the present disclosure.

[0034] FIG. **7** is a cross-sectional view schematically illustrating the configuration of the first suspension arm and the limiting member in accordance with an embodiment of the present disclosure.

[0035] FIG. **8** is an exploded perspective view schematically illustrating the configuration of the first suspension arm and the limiting member in accordance with an embodiment of the present disclosure.

[0036] FIG. **9** is a perspective view schematically illustrating the configuration of a limiting joint in accordance with an embodiment of the present disclosure.

[0037] FIG. **10** is a front view schematically illustrating the configuration of the limiting joint in accordance with an embodiment of the present disclosure.

[0038] FIG. **11** is a cross-sectional view taken along line **11**-**11**′ in FIG. **10**.

[0039] FIG. **12** is a cross-sectional view taken along line **12**-**12**′ in FIG. **10**.

[0040] FIG. **13** is an operation view schematically illustrating an operation of adjusting a steering angle of a wheel.

[0041] FIG. **14** is an operation view schematically illustrating a bump and rebound operation of the wheel.

DETAILED DESCRIPTION

[0042] Hereinafter, an embodiment of the present disclosure is described with reference to the accompanying drawings.

[0043] In this process, the thicknesses of lines or the sizes of elements illustrated in the drawings may be exaggerated for the purpose of clarity and convenience of explanation. Furthermore, terms to be described below are terms defined in consideration of functions thereof in the present disclosure and may be changed according to the intention of a user or an operator, or practice. Accordingly, such terms should be defined based on the disclosure over the present specification.

[0044] Furthermore, in the present specification, when a certain part is referred to as being "connected (or coupled) to" another part, it may indicate that the former part is directly connected (or coupled) to the latter part or indirectly connected (or coupled) to the latter part with another part interposed therebetween. In the present specification, when a certain part "includes (or comprises)" a certain component, it means that the part does not exclude another component but may further "include (or comprise)" another component, unless referred to the contrary.

[0045] Furthermore, the same reference numerals may refer to the same components throughout the present specification. Even though the same reference numerals or similar reference numerals are not mentioned or described in a specific drawing, the reference numerals may be described based on other drawings. Furthermore, even though there is a portion which is not indicated by reference

numerals in a specific drawing, the portion may be described based on other drawings. Furthermore, the number, shapes, and sizes of detailed components included in the drawings of the present application and relative differences in the sizes are set for convenience of understanding, and do not limit embodiments and may be implemented in various forms.

[0046] FIG. **1** is a view schematically illustrating an installation state of a suspension apparatus in accordance with an embodiment of the present disclosure, FIG. **2** is a perspective view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure, FIG. **3** is a side view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure, FIG. **4** is a front view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure, and FIG. **5** is an exploded perspective view schematically illustrating the configuration of the suspension apparatus in accordance with an embodiment of the present disclosure.

[0047] Referring to FIGS. **1** to **5**, a plurality of suspension apparatuses **1** may be provided. The plurality of suspension apparatuses **1** may be individually installed on respective wheels **2**.

[0048] One suspension apparatus **1** among the plurality of suspension apparatuses **1** is described below as an example. The description of one suspension apparatus **1** to be described below may be equally applied to the remaining suspension apparatuses **1**.

[0049] A vehicle body V is a component that forms the exterior and framework of a vehicle and may include a main body, a chassis frame, and a subframe.

[0050] The following is an example in which, based on FIGS. **1** to **5**, a longitudinal direction of the vehicle body V refers to a direction parallel to an X-axis direction, a width direction of the vehicle body V refers to a direction parallel to a Y-axis direction, and a direction perpendicular to the ground refers to a direction parallel to a Z-axis direction.

[0051] The suspension apparatus **1** in accordance with the present embodiment includes a drive unit **100**, a first knuckle **200**, a second knuckle **300**, a first suspension arm **400**, and a limiting member **500**.

[0052] The drive unit **100** may serve as a component that rotates the wheel **2** by providing a driving force to the wheel **2** when the vehicle is running. The drive unit **100** may be installed inside the wheel **2** of the vehicle.

[0053] The drive unit **100** in accordance with the present embodiment may be disposed inside the wheel **2**, and exemplified as various types of in-wheel motors including a stator that forms a magnetic field by receiving power from a vehicle's battery or the like and a rotor that is rotated by electromagnetic interaction between the stator and the rotor and rotates the wheel **2**. The stator and the rotor have their central axes coaxial with a central axis C of the wheel **2**, and may be stacked concentrically on the inside of the wheel **2**.

[0054] The first knuckle **200** may be connected to the drive unit **100** to rotate around a first axis A**1**, and may change a steering angle of the wheel **2**. The first knuckle **200** may serve as a component that supports the drive unit **100** disposed inside the wheel **2** and transmits a steering force to the wheel **2**.

[0055] The first knuckle **200** in accordance with the present embodiment may be disposed between the drive unit **100** and the vehicle body V. The first knuckle **200** may be disposed to face the drive unit **100** along a direction parallel to the central axis C of the wheel **2**. The first knuckle **200** may be connected to the stator of the drive unit **100** by various types of coupling methods such as bolting and welding. The first knuckle **200** may rotatably support the rotor of the drive unit **100** via a wheel bearing **201**. The first knuckle **200** may be manufactured by molding a metal-based material using a casting or the like in order to ensure sufficient rigidity.

[0056] The first knuckle **200** may be rotatably supported around the first axis A**1** by the second knuckle **300** to be described below. The first knuckle **200** may be connected to a tie rod **202**, and may receive a steering force generated by a driver's steering wheel operation through the tie rod

202. The first knuckle **200** may rotate clockwise or counterclockwise around the first axis A**1** by the received steering force, and change the steering angle of the wheel **2**.

[0057] The first axis A**1** may serve as a steering axis of the wheel **2**. As illustrated in FIG. **3**, the first axis A**1** may be inclinedly disposed with respect to a third axis A**3** extending perpendicular to the ground and the width direction of the vehicle body V to form a predetermined kingpin angle. Accordingly, the first knuckle **200** may reduce a steering force required for steering the wheel **2** and reduce an impact applied to the vehicle during braking.

[0058] As illustrated in FIG. **4**, the first axis A**1** may be inclinedly disposed with respect to the third axis A**3** and the longitudinal direction of the vehicle body V to form a predetermined caster angle. For example, the first axis A**1** may be disposed to be inclined at an angle of about 9.1° from the third axis A**3** toward the direction (X-axis in FIG. **4**) parallel to the longitudinal direction of the vehicle body V. Accordingly, the first knuckle **200** may improve straight driving performance of the vehicle and provide a restoring force to the wheel **2** after cornering.

[0059] The specific shape of the first knuckle **200** is not limited to the shape illustrated in FIG. **5**, and the first knuckle **200** can be designed in various ways within the technical idea of a shape that may be connected to the drive unit **100** and rotated around the first axis A**1**.

[0060] The second knuckle **300** may be connected to the first knuckle **200** to rotatably support the first knuckle **200** around the first axis A**1**. The second knuckle **300** may move along a second axis A**2** spaced apart from the first axis A**1** during a bump and rebound motion of the wheel **2**. That is, the second knuckle **300** may serve as a component that provides a support force to the first knuckle **200** and guides the direction of suspension behavior of the wheel **2**.

[0061] The second knuckle **300** in accordance with the present embodiment may be disposed between the first knuckle **200** and the vehicle body V. The second knuckle **300** may be disposed to face the first knuckle **200** along a direction parallel to the central axis C of the wheel **2**. That is, the drive unit **100**, the first knuckle **200**, and the second knuckle **300** may be sequentially disposed from the wheel **2** toward the vehicle body V.

[0062] A longitudinal direction of the second knuckle **300** may be disposed in parallel to the second axis A**2**. Both upper and lower ends of the second knuckle **300** may be disposed to be spaced apart from each other along the second axis A**2**. The second knuckle **300** may rectilinearly reciprocate up and down along the second axis A**2** during the bump and rebound behavior of the wheel **2**.

[0063] The second axis A**2** may serve as a suspension axis of the wheel **2**. As illustrated in FIG. **3**, the first axis A**1** and the second axis A**2** may be spaced apart from each other along the width direction of the vehicle body V. That is, the first knuckle **200** and the second knuckle **300** may separate the steering axis of the wheel **2** and the suspension axis of the wheel **2** from each other. A distance between the second axis A**2** and the wheel **2** may be greater than a distance between the first axis A**1** and the wheel **2**. Accordingly, the first axis A**1** serving as the steering axis of the wheel **2** is disposed at a position relatively close to the wheel **2**, so that the first knuckle **200** and the second knuckle **300** may reduce a kingpin offset value and improve the driving and braking stability of the vehicle.

[0064] As illustrated in FIG. **4**, the second axis A**2** may be inclinedly disposed with respect to the third axis A**3** and the longitudinal direction of the vehicle body V to form a predetermined caster angle. For example, the second axis A**2** may be disposed to be inclined at an angle of about **9**.**1**° from the third axis A**3** toward a direction (X-axis in FIG. **4**) parallel to the longitudinal direction of the vehicle body V.

[0065] The second knuckle **300** may include a knuckle joint **301** that rotatably supports the first knuckle **200**. The knuckle joint **301** may include various types of connection means that may connect different parts, such as ball joints, to be relatively rotatable. The knuckle joint **301** may be provided as a pair. The pair of knuckle joints **301** may be disposed to be spaced apart from each other along the first axis A**1**. The pair of knuckle joints **301** may be individually connected to different positions of the first knuckle **200** spaced apart from the second knuckle **300** along the first

axis A**1**.

[0066] The second knuckle **300** may further include a first connection part **310** and a second connection part **320**. The first connection part **310** and the second connection part **320** may be respectively disposed at both ends of the second knuckle **300** spaced apart from each other along the second axis A**2**. The first connection part **310** and the second connection part **320** may each be formed to have a shape of a hole penetrating the second knuckle **300**. The central axes of the first connection part **310** and the second connection part **320** may be disposed perpendicular to the second axis A**2** and the central axis C of the wheel **2**. The following is an example in which the first connection part **310** is located below the second connection part **320**; however, the first connection part **310** and the second connection part **320** are not limited thereto and the first connection part **310** may be located above the second connection part **320**.

[0067] The specific shape of the second knuckle **300** is not limited to the shape illustrated in FIG. **5**, and the second knuckle **300** can be designed in various ways within the technical idea of a shape that supports the first axis A**1** so that the first knuckle **200** can be rotated and can reciprocate along the second axis A**2** during the bump and rebound motion of the wheel **2**.

[0068] The first suspension arm **400** may be connected to the second knuckle **300** to support the second knuckle **300** with respect to the vehicle body V. The following description is an example in which the first suspension arm **400** is connected to the first connection part **310** of the second knuckle **300**; however, the first suspension arm **400** is not limited thereto and may be connected to the second connection part **320** of the second knuckle **300**.

[0069] FIG. **6** is an enlarged view schematically illustrating the configuration of the first suspension arm and the limiting member in accordance with an embodiment of the present disclosure, FIG. **7** is a cross-sectional view schematically illustrating the configuration of the first suspension arm and the limiting member in accordance with an embodiment of the present disclosure, and FIG. **8** is an exploded perspective view schematically illustrating the configuration of the first suspension arm and the limiting member in accordance with an embodiment of the present disclosure.

[0070] Referring to FIGS. **1** to **8**, the first suspension arm **400** in accordance with the present embodiment may include a first arm body **410**, a joint body **420**, and a first joint **430**.

[0071] The first arm body **410** may form a schematic external appearance of the first suspension arm **400**, and extend from the vehicle body V toward the second knuckle **300**.

[0072] The first arm body **410** in accordance with the present embodiment may be formed to have a wishbone shape. However, the shape of the first arm body **410** is not limited thereto, and the first arm body **410** can be designed in various shapes such as a link arm. The first arm body **410** may be disposed between the second knuckle **300** and the vehicle body V.

[0073] One end of the first arm body **410** may be rotatably connected to the vehicle body V via a bush, bearing, joint, or the like. One end of the first arm body **410** may rotate clockwise or counterclockwise around a direction parallel to the longitudinal direction of the vehicle body V during the bump and rebound motion of the wheel **2**.

[0074] The other end of the first arm body **410** may be disposed to face one side of the first connection part **310** of the second knuckle **300**. The other end of the first arm body **410** may be spaced apart from the first connection part **310** along the central axis of the first connection part **310**.

[0075] The joint body **420** may be connected to the second knuckle **300**. The joint body **420** in accordance with the present embodiment may be formed to have a bar shape having a first end **421** and a second end **422**. The joint body **420** may be disposed so that its central axis is coaxial with the central axis of the first connection part **310**. The joint body **420** may be inserted into the first connection part **310**. An outer surface of the joint body **420** may be fixed to an inner surface of the first connection part **310**. Accordingly, the joint body **420** may not rotate around the central axis of the first connection part **310**.

[0076] The first end **421** and the second end **422** may protrude to both sides of the second knuckle **300** with respect to the first connection part **310**. As the central axis of the joint body **420** is located on the same axis as the central axis of the first connection part **310**, the first end **421** and the second end **422** may be spaced apart from each other along a direction intersecting the second axis A**2**, more specifically, a direction perpendicular to the second axis A**2**. The first end **421** may be disposed to face the other end of the first arm body **410** facing one side of the first connection part **310**.
[0077] The first joint **430** may be connected to the first end **421** to rotatably support the first arm body **410** with respect to the joint body **420**. The first joint **430** in accordance with the present embodiment may extend from the first end **421** toward the other end of the first arm body **410**. The first joint **430** may be inserted into the other end of the first arm body **410**.
[0078] The first joint **430** may be formed to have a spherical shape. An outer surface of the first joint **430** may be in rolling contact with the inner surface of the other end of the first arm body **410**. Accordingly, the first joint **430** may be rotated in multiple axes with respect to the first arm body **410** during the suspension behavior of the wheel **2**, and may absorb relative displacement between the second knuckle **300** and the first arm body **410** by a caster angle of the second axis A**2**.
[0079] The limiting member **500** may be connected to the first suspension arm **400** to limit the rotation of the second knuckle **300** around the second axis A**2**. More specifically, the limiting member **500** may serve as a configuration of limiting the rotation of the second knuckle **300** around the second axis A**2** by a rotational force applied from the first knuckle **200** when the first knuckle **200** rotates around the first axis A**1**. Accordingly, the limiting member **500** may prevent the second knuckle **300** from rotating together with the first knuckle **200** when steering the wheel **2**, prevent a kingpin offset from arbitrarily increasing, and improve the driving stability of the vehicle.
[0080] Both sides of the limiting member **500** may be connected to the vehicle body V and the second end **422** of the joint body **420**, respectively. Accordingly, the first arm body **410** and the limiting member **500** may connect, to the vehicle body V, the first end **421** and the second end **422** of the joint body **420** spaced apart from each other in the direction intersecting the second axis A**2**, thereby suppressing the rotation of the second knuckle **300** around the second axis A**2**.
[0081] The limiting member **500** may include a limiting link **510** and a limiting joint **520**.
[0082] The limiting link **510** may be spaced apart from the first arm body **410** and may extend from the vehicle body V toward the second knuckle **300**.
[0083] The limiting link **510** in accordance with the present embodiment may be formed to have the shape of a link arm. However, the shape of the limiting link **510** is not limited thereto, and the limiting link **510** can be designed in various shapes such as a wishbone. The limiting link **510** may be disposed between the second knuckle **300** and the vehicle body V.
[0084] One end of the limiting link **510** may be rotatably connected to the vehicle body V via a bush, a bearing, a joint, or the like. One end of the limiting link **510** may rotate clockwise or counterclockwise around a direction parallel to the longitudinal direction of the vehicle body V during the bump and rebound motion of the wheel **2**.
[0085] The other end of the limiting link **510** may be spaced apart from the first connection part **310** along the central axis of the first connection part **310**. That is, the other end of the first arm body **410** and the other end of the limiting link **510** may be disposed on both sides of the second knuckle **300** with the first connection part **310** interposed therebetween. The other end of the limiting link **510** may be disposed to face the second end **422** of the joint body **420** protruding from the other side of the first connection part **310** of the second knuckle **300**.
[0086] The limiting joint **520** may be connected to the second end **422** of the joint body **420** to rotatably support the limiting link **510** with respect to the second end **422**.
[0087] FIG. **9** is a perspective view schematically illustrating the configuration of the limiting joint in accordance with an embodiment of the present disclosure, FIG. **10** is a front view schematically illustrating the configuration of the limiting joint in accordance with an embodiment of the present

disclosure, FIG. **11** is a cross-sectional view taken along line **11**-**11**′ in FIG. **10**, and FIG. **12** is a cross-sectional view taken along line **12**-**12**′ in FIG. **10**.

[0088] A Z′ axis illustrated in FIGS. **9** to **12** refers to an axis parallel to the second axis A**2** illustrated in FIGS. **1** to **4**, and a Y′ axis may refer to an axis parallel to the Y axis illustrated in FIGS. **1** to **4**.

[0089] Referring to FIGS. **1** to **12**, the limiting joint **520** in accordance with the present embodiment may include an outer body **521**, an inner body **522**, and a stud **523**.

[0090] The outer body **521** may form a schematic external appearance of the limiting joint **520** and may be connected to the limiting link **510**. The outer body **521** in accordance with the present embodiment may be formed to have a cylindrical shape with openings at both ends thereof. The outer body **521** may be inserted into and fixed to the other end of the limiting link **510**. An outer peripheral surface of the outer body **521** may be press-fitted to the inner peripheral surface of the other end of the limiting link **510** or may be fixed thereto by welding. An inner peripheral surface of the outer body **521** may be disposed to surround an entire peripheral surface of the second end **422**. The inner peripheral surface of the outer body **521** may be spaced apart from an outer peripheral surface of the second end **422** by a predetermined distance.

[0091] The outer body **521** may include a bearing portion **521***a* for rotatably supporting a stud **523** to be described below. The bearing portion **521***a* may be manufactured separately from the outer body **521** and then coupled to the outer body **521**. Alternatively, the bearing portion **521***a* may be formed integrally with the outer body **521**. The bearing portion **521***a* may be formed to protrude from the inner peripheral surface of the outer body **521** toward the second end **422** by a predetermined distance.

[0092] The inner body **522** may be disposed inside the outer body **521** and connected to the second end **422**. The inner body **522** in accordance with the present embodiment may be formed to have a hollow rod shape. The second end **422** may be inserted into the inner body **522** through the hollow of the inner body **522**. An inner peripheral surface of the inner body **522** may be fixed to the outer peripheral surface of the second end **422** by press fitting, welding, or the like. A central axis of the inner body **522** may be disposed to be coaxial with a central axis of the joint body **420**. The central axis of the inner body **522** may be disposed perpendicular to the second axis A**2**.

[0093] The stud **523** may be connected to the inner body **522** and may be rotatably in contact with the outer body **521**. The stud **523** in accordance with the present embodiment may protrude from an outer peripheral surface of the inner body **522** toward the inner peripheral surface of the outer body **521**. An outer surface of the stud **523** may be rotatably in contact with the bearing portion **521***a* of the outer body **521**.

[0094] The stud **523** may be formed to have a spherical shape. The outer surface of the stud **523** may be in rolling contact with an inner surface of the bearing portion **521***a*. Accordingly, the stud **523** may be rotated in multiple axes with respect to the outer body **521** during the suspension behavior of the wheel **2**, and may absorb relative displacement between the second knuckle **300** and the first arm body **410** by the caster angle of the second axis A**2**. In this case, as the rotational motion of the second knuckle **300** around the second axis A**2** is suppressed by the length rigidity of the first arm body **410** and the limiting link **510**, the rotation of the first joint **430** and the stud **523** around a direction parallel to the second axis A**2** may also be selectively suppressed.

[0095] The limiting joint **520** may further include a dust cover **524**.

[0096] The dust cover **524** may serve as a component for blocking foreign substances from entering the interior of the outer body **521**. The dust cover **524** in accordance with the present embodiment may be formed to have a hollow corrugated tube shape with both sides open. The dust cover **524** may be disposed to surround the end of the inner body **522**. Both sides of the dust cover **524** may be fixed to the outer peripheral surface of the outer body **521** and the outer peripheral surface of the inner body **522**, respectively. The dust cover **524** may be made of an elastically deformable material such as rubber or silicone so as not to interfere with relative rotation between

the outer body **521** and the inner body **522**.
[0097] The dust cover **524** may be provided as a pair. The pair of dust covers **524** may be symmetrically disposed on both sides of the outer body **521**.
[0098] The limiting joint **520** may further include a stopper **525**.
[0099] The stopper **525** may be disposed to surround the inner body **522** and may restrict the stud **523** from rotating about a direction parallel to the second axis A**2**. The stopper **525** may serve as a component that additionally suppresses the rotational motion of the second knuckle **300** about the second axis A**2** in addition to the length rigidity of the first arm body **410** and the limiting link **510**.
[0100] The stopper **525** in accordance with the present embodiment may extend from the end of the outer body **521** along the longitudinal direction of the inner body **522**. The stopper **525** may be formed to have a hollow ring shape with both sides open. An inner surface of the stopper **525** may be disposed to surround the entire outer peripheral surface of the inner body **522**.
[0101] The stopper **525** may be formed to have a substantially oval cross-sectional shape. For example, as illustrated in FIGS. **10** to **12**, a width t**1** of the stopper **525** parallel to the second axis A**2** may be greater than a width t**2** of the stopper **525** intersecting the second axis A**2**, more specifically, perpendicular to the second axis A**2**. The width of the stopper **525** may refer to a distance between the inner surfaces of the stopper **525** perpendicular to the longitudinal direction of the joint body **420** and passing through the central axis of the joint body **420**. Accordingly, the stopper **525** may suppress the rotation of the second knuckle **300** about the second axis A**2** by reducing the range in which the stud **523** can rotate about the direction parallel to the second axis A**2**.
[0102] The width t**2** of the stopper **525** perpendicular to the second axis A**2** may be equal to an outer diameter of the inner body **522**. Accordingly, the stopper **525** may maintain a state in contact with the outer peripheral surface of the inner body **522** in a direction perpendicular to the second axis A**2**, thereby more effectively suppressing the rotation of the second knuckle **300** about the second axis A**2**.
[0103] The suspension apparatus in accordance with the present embodiment may further include a second suspension arm **600**.
[0104] The second suspension arm **600** may be spaced apart from the first suspension arm **400** and connected to the second knuckle **300**. The second suspension arm **600** may serve as a configuration of supporting the second knuckle **300** with respect to the vehicle body V at a different position from the first suspension arm **400**. The following is an example in which the second suspension arm **600** is connected to the second connection part **320** of the second knuckle **300**; however, the second suspension arm **600** is not limited thereto and can also be connected to the first connection part **310** of the second knuckle **300**.
[0105] The second suspension arm **600** in accordance with the present embodiment may include a second arm body **610** and a second joint **620**.
[0106] The second arm body **610** may form a schematic external appearance of the second suspension arm **600** and may extend from the vehicle body V toward the second knuckle **300**.
[0107] The second arm body **610** in accordance with the present embodiment may be formed to have a wishbone shape. However, the shape of the second arm body **610** is not limited thereto, and the second arm body **610** can be designed in various shapes such as a link arm. The second arm body **610** may be disposed between the second knuckle **300** and the vehicle body V. The second arm body **610** may be disposed to be spaced apart from the first arm body **410** along the second axis A**2**.
[0108] One end of the second arm body **610** may be rotatably connected to the vehicle body V via a bush, bearing, joint, or the like. One end of the second arm body **610** may rotate clockwise or counterclockwise around a direction parallel to the longitudinal direction of the vehicle body V during the bump and rebound motion of the wheel **2**. The other end of the second arm body **610** may be disposed to face the second connection part **320** of the second knuckle **300**.

[0109] The second joint **620** may be connected to the second knuckle **300** to rotatably support the second arm body **610** with respect to the second knuckle **300**. The second joint **620** in accordance with the present embodiment may be inserted into the second connection part **320**. Both sides of the second joint **620** may protrude from the second connection part **320** to both sides of the second knuckle **300**, respectively. Both sides of the second joint **620** may be connected to different positions of the other end of the second arm body **610** facing the second connection part **320**, respectively.
[0110] The second joint **620** may include a connection means, such as a ball joint, that can support the second arm body **610** to be rotatable in multiple axes with respect to the second knuckle **300**. Accordingly, the second arm body **610** may be rotated in multiple axes with respect to the second knuckle **300** during the suspension behavior of the wheel **2**, and may absorb relative displacement between the second knuckle **300** and the second arm body **610** by the caster angle of the second axis A**2**.
[0111] The suspension apparatus in accordance with the present embodiment may further include a shock absorber **700**. For example, the shock absorber **700** may be a combination of a shock absorber and a coil spring (e.g., a McPherson strut) or include other types of suspension systems known in the art.
[0112] The shock absorber **700** may absorb shock or vibration transmitted from a road surface to the vehicle body through the wheel **2**.
[0113] The shock absorber **700** in accordance with the present embodiment may be exemplified with various types of shock absorbers including a cylinder that is expandable in the longitudinal direction and a spring that elastically supports the expansion and contraction motion of the cylinder. The shock absorber **700** may be disposed in parallel to the second axis A**2** in the longitudinal direction. One end of the shock absorber **700** may be connected to the first arm body **410**, and the other end thereof may be connected to a wheel housing (not illustrated) of the vehicle.
[0114] The suspension apparatus in accordance with the present embodiment may further include a braking unit **800**.
[0115] The braking unit **800** may apply or release a braking force by interfering with the rotation of the wheel **2**.
[0116] The braking unit **800** in accordance with the present embodiment may include a brake disk **810** and a caliper brake **820**.
[0117] The brake disc **810** may be connected to the wheel **2** or the drive unit **100** to rotate in conjunction with the rotation of the wheel **2**. The brake disc **810** in accordance with the present embodiment may be formed to have a disk shape and installed inside the wheel **2**. The brake disc **810** may be disposed so that its central axis is located on the same line as the central axis of the wheel **2**. The brake disc **810** may be integrally connected to the wheel **2** or the rotor of the drive unit **100** by bolting or the like. Accordingly, the brake disc **810** may rotate about the central axis together with the wheel **2** when the wheel **2** rotates. A diameter of the brake disc **810** can be designed in various ways depending on the diameter of the wheel **2**, the size of the drive unit **100**, and the like.
[0118] The caliper brake **820** may apply a braking force by pressing the brake disc **810** when braking the vehicle. The caliper brake **820** in accordance with the present embodiment may include a brake pad disposed to face the brake disc **810**, a caliper housing coupled to the first knuckle **200** to support the brake pad to enable reciprocating movement, and a piston that is installed in the caliper housing to be able to move forward and backward and presses the brake pad toward the brake disc **810** depending on the direction of movement or releases the pressure on the brake pad.
[0119] An operation of the suspension apparatus in accordance with an embodiment of the present invention is described below in detail.
[0120] FIG. **13** is an operation view schematically illustrating the operation of adjusting the steering angle of the wheel.

[0121] Referring to FIGS. **1** to **13**, when steering the vehicle, a steering force generated by a driver's steering wheel operation is transmitted to the first knuckle **200** through the tie rod **202**.
[0122] The first knuckle **200** rotates clockwise or counterclockwise about the first axis A**1** and changes the steering angle of the wheel **2**.
[0123] As the first knuckle **200** rotates around the first axis A**1**, a rotational force is generated in the second knuckle **300** around the second axis A**2**.
[0124] The rotational force of the second knuckle **300** is transmitted to the joint body **420** through the first connection part **310**, and the first end **421** and the second end **422** of the joint body **420** apply a tensile force or a compressive force to the first arm body **410** and the limiting link **510**, respectively.
[0125] The tensile force or compressive force applied to the first arm body **410** and the limiting link **510** is offset by the rigidity of the first arm body **410** and the limiting link **510**, and the rotation of the second knuckle **300** around the second axis A**2** can be suppressed.
[0126] In this process, the rotation of the second knuckle **300** around the second axis A**2** may be suppressed multiple times by a reaction force generated as the inner body **522** of the limiting joint **520** contacts the stopper **525** in the direction perpendicular to the second axis A**2**.
[0127] FIG. **14** is an operation view schematically illustrating the bump and rebound operation of the wheel.
[0128] Referring to FIG. **14**, when the wheel **2** bumps and rebounds due to unevenness of a road surface or the like, the second knuckle **300** connected to the wheel **2** through the first knuckle **200** is rectilinearly reciprocated along the second axis A**2** together with the wheel **2**.
[0129] One end of the first arm body **410** and one end of the limiting link **510** are rotated relative to the vehicle body V by the reciprocating movement of the second knuckle **300**.
[0130] The second axis A**2** is disposed to be inclined at a predetermined angle from the third axis A**3** in the longitudinal direction of the vehicle body V, and as the rotational central axis of one end of the first arm body **410** and the rotational central axis of one end of the limiting link **510** are disposed in parallel with the longitudinal direction of the vehicle body V, a torsional load is generated between the other ends of the first arm body **410** and the limiting link **510** and the second knuckle **300**.
[0131] The first joint **430** and the limiting joint **520** rotate the first arm body **410** and the limiting link **510** relative to the second knuckle **300**, respectively.
[0132] Through the angular displacement of the first arm body **410** and the limiting link **510** with respect to the second knuckle **300** described above, the torsional load generated between the other ends of the first arm body **410** and the limiting link **510** and the second knuckle **300** can be canceled out.
[0133] The suspension apparatus may be capable of countering an increase in torque steer due to an increase in a kingpin offset (due to an increase in the weight of the wheel), in response to at least one of the driving force being applied, the braking force being applied, or a combination thereof. This type of suspension may be used where there is an increase in the weight of the wheels of the vehicle, e.g., in an electric vehicle (EV) with wheels including one or more in-wheel motors.
[0134] Although the present disclosure has been described with reference to the embodiments illustrated in the drawings, the embodiments of the disclosure are for illustrative purposes only, and those skilled in the art will appreciate that various modifications and other equivalent embodiments are possible from the embodiments. Thus, the true technical scope of the present disclosure should be defined by the following claims.

Claims

1. A suspension apparatus comprising: a drive unit installed inside a wheel; a first knuckle connected to the drive unit and configured to rotate around a first axis; a second knuckle connected

to the first knuckle and configured to move along a second axis spaced apart from the first axis; a first suspension arm connected to the second knuckle and configured to support the second knuckle with respect to a vehicle body; and a limiting member connected to the first suspension arm and configured to limit rotation of the second knuckle around the second axis.

2. The suspension apparatus according to claim 1, wherein a distance between the second axis and the wheel is greater than a distance between the first axis and the wheel.

3. The suspension apparatus according to claim 1, wherein the drive unit, the first knuckle, and the second knuckle are sequentially disposed from the wheel toward the vehicle body.

4. The suspension apparatus according to claim 1, wherein the first suspension arm comprises: a first arm body configured to extend from the vehicle body toward the second knuckle; a joint body connected to the second knuckle and comprising a first end and a second end; and a first joint connected to the first end and configured to rotatably support the first arm body.

5. The suspension apparatus according to claim 4, wherein the first end of the joint body protrudes at one side of the second knuckle, and wherein the second end of the joint body protrudes at another side of the second knuckle.

6. The suspension apparatus according to claim 4, wherein the first end and the second end are spaced apart from each other in a direction intersecting the second axis.

7. The suspension apparatus according to claim 4, wherein the second axis is inclined with respect to a third axis extending vertically from a ground and a longitudinal direction of the vehicle body, and wherein the first joint has a spherical shape.

8. The suspension apparatus according to claim 4, wherein both sides of the limiting member are respectively connected to the vehicle body and the second end.

9. The suspension apparatus according to claim 8, wherein the limiting member comprises: a limiting link spaced apart from the first arm body and configured to extend from the vehicle body toward the second knuckle; and a limiting joint connected to the second end and configured to rotatably support the limiting link with respect to the second end.

10. The suspension apparatus according to claim 9, wherein the limiting joint comprises: an outer body connected to the limiting link; an inner body disposed inside the outer body and connected to the second end; and a stud connected to the inner body and configured to rotatably contact with the outer body.

11. The suspension apparatus according to claim 10, wherein the second axis is inclined with respect to a third axis extending vertically from a ground and a longitudinal direction of the vehicle body, and wherein the stud has a spherical shape.

12. The suspension apparatus according to claim 10, wherein the limiting joint further comprises: a stopper disposed to surround the inner body and configured to restrict the stud from rotating about a direction parallel to the second axis.

13. The suspension apparatus according to claim 12, wherein a width of the stopper parallel to the second axis is greater than a width of the stopper intersecting the second axis.

14. The suspension apparatus according to claim 1, further comprising: a second suspension arm spaced apart from the first suspension arm and connected to the second knuckle.

15. The suspension apparatus according to claim 14, wherein the second knuckle comprises a first connection part and a second connection part spaced apart from each other along the second axis, and wherein the first suspension arm and the second suspension arm are respectively connected to the first connection part and the second connection part.

16. A suspension apparatus for a vehicle, the apparatus comprising: a drive unit installed inside a wheel and configured to provide a driving force to rotate the wheel; a brake unit configured to provide a braking force to the wheel; a first knuckle connected to the drive unit and configured to rotate around a first axis; a second knuckle connected to the first knuckle and configured to move along a second axis spaced apart from the first axis; a first suspension arm connected to the second knuckle and configured to support the second knuckle with respect to a vehicle body; and a limiting

member connected to the first suspension arm and configured to limit rotation of the second knuckle around the second axis.

17. The apparatus according to claim 16, wherein the drive unit includes a motor.

18. The apparatus according to claim 16, wherein the first knuckle, the second knuckle, the first suspension arm and the limiting member are configured to counter an increase in torque steer due to an increase in a kingpin offset, in response to at least one of the driving force being applied by the drive unit, the braking force being applied by the brake unit, or a combination thereof.

19. The apparatus according to claim 16, wherein a distance between the second axis and the wheel is greater than a distance between the first axis and the wheel, and wherein the drive unit, the first knuckle, and the second knuckle are sequentially disposed from the wheel toward the vehicle body.

20. The apparatus according to claim 16, wherein the first suspension arm comprises: a first arm body configured to extend from the vehicle body toward the second knuckle; a joint body connected to the second knuckle and comprising a first end and a second end; and a first joint connected to the first end and configured to rotatably support the first arm body.