

VEHICLE STEERING SYSTEM, AND VEHICLE HAVING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to Chinese Patent Application 202023351625.2 and No. 202011630594.6 filed on December 30, 2020. The entire content of the above-referenced applications is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to the field of vehicle technologies, and more specifically, a vehicle steering system and a vehicle having the same.

BACKGROUND

[0003] In the related art, an upper portion of a first steering shaft of a vehicle is usually fixed to a steering wheel, and a lower portion of the first steering shaft is usually connected to a steering gear. Therefore, a steering torque of a driver acting on the steering wheel is transmitted to the steering gear to realize the steering of the vehicle. However, the vehicle steering system has relatively undiversified functions. When the vehicle has emerging functions such as an on-board multimedia function, a drive-by-wire function, and an automatic driving function, real feeling of steering of the vehicle needs to be simulated to improve user experience.

SUMMARY

[0004] The present disclosure is intended to resolve at least one of the technical problems existing in the related art. An object of the present disclosure is to provide a vehicle steering system. The vehicle steering system may simulate a steering feeling during transmission

of a steering torque by a first steering shaft and a steering gear when the first steering shaft and the steering gear interrupt the transmission of the steering torque, thereby effectively improving user experience.

[0005] Another object of the present disclosure is to provide a vehicle having the vehicle steering system.

[0006] The vehicle steering system according to an embodiment of the present disclosure includes: a housing; a first steering shaft, rotatably arranged in the housing, where the first steering shaft is configured to be coupled to a steering gear to transmit a steering torque, and the first steering shaft is configured to be decoupled from the steering gear to interrupt the transmission of the steering torque; and a feeling simulator, connected to the first steering shaft, where the feeling simulator is configured to simulate a steering feeling during the transmission of the steering torque by the first steering shaft and the steering gear when the first steering shaft and the steering gear interrupt the transmission of the steering torque.

[0007] In the vehicle steering system according to the embodiments of the present disclosure, the feeling simulator is arranged and configured to simulate a steering feel when the first steering shaft and the steering gear transfer the steering torque in a case that the first steering shaft and the steering gear are disconnected from transmission of the steering torque. When the vehicle has emerging functions such as an on-board multimedia function, a drive-by-wire function, and an autonomous driving function, the feeling simulator can be configured to simulate the real steering feel such as steering damping feeling and the restoring force, and ensure the authenticity of simulation and effectively improve the user experience.

[0008] According to some embodiments of this application, the feeling simulator includes: a feeling driver, having an output shaft and arranged on the housing; a driving member,

fixed on the output shaft; and a driven member, fixed on the first steering shaft and engaged with the driving member.

[0009] According to some embodiments of the present disclosure, the vehicle steering system further includes: a rotation angle detector, configured to detect a rotation direction of the first steering shaft; and a controller, configured to communicate with each of the rotation angle detector and the feeling driver, where when the first steering shaft turns, the controller controls the feeling driver to provide resistance against the turning of the first steering shaft; and when the first steering shaft restores, the controller controls the feeling driver to provide assistance to the restoring of the first steering shaft.

[0010] According to some embodiments of the present disclosure, the vehicle steering system further includes: a torque detector, configured to detect a driving condition of a vehicle and transmit a first torque signal; and a controller, configured to communicate with each of the torque detector and the feeling driver, receive the first torque signal, and control, according to the first torque signal, the feeling driver to provide the first steering shaft with a road feel simulation torque that simulates a road feel torque transmitted by the first steering shaft and the steering gear.

[0011] According to some embodiments of the present disclosure, the vehicle steering system further includes: a driving computer, configured to communicate with the controller and detect a driving attitude of the vehicle and transmit a second torque signal to the controller, where the controller is configured to control, according to the second torque signal, the feeling driver to provide the first steering shaft with the road feel simulation torque that simulates the road feel torque transmitted by the first steering shaft and the steering gear.

[0012] According to some embodiments of the present disclosure, the vehicle steering

system further includes: a safety detector, configured to detect whether a driver drives safely; and a controller, configured to communicate with each of the safety detector and the feeling driver, where the controller controls the feeling driver to provide a vibration force to drive the first steering shaft to alternately rotate forward and backward when the safety detector detects a safety risk in the driving.

[0013] According to some embodiments of the present disclosure, the safety detector includes at least one of a fatigue detector, a lane departure detector, a collision detector, a lane change blind area detector, and a reversing collision detector.

[0014] According to some embodiments of the present disclosure, the housing includes: a body, where the first steering shaft and the driven member are both arranged in the body; and an accommodating portion, protruding from an outer surface of the body, where an interior of the accommodating portion is in communication with an interior of the body; and the driving member is arranged in the accommodating portion.

[0015] According to some embodiments of the present disclosure, a part of the driving member extends into the body and is engaged with the driven member.

[0016] According to some embodiments of the present disclosure, a free end of the output shaft extends into the accommodating portion from one end of the accommodating portion and is fixed to one end of the driving member, a support member is arranged on the other end of the accommodating portion, and the other end of the driving member rotatably extends through the support member.

[0017] According to some embodiments of the present disclosure, the other end of the accommodating portion is open, and the other end of the accommodating portion is provided with a detachable end cover.

[0018] According to some embodiments of the present disclosure, a central axis of the accommodating portion is perpendicular to a central axis of the body.

[0019] According to some embodiments of the present disclosure, the accommodating portion and the body are formed in one piece.

[0020] According to some embodiments of the present disclosure, the feeling driver is detachably connected to the accommodating portion.

[0021] According to some embodiments of the present disclosure, the driving member is a worm, and the driven member is a worm gear meshed with the worm.

[0022] According to some embodiments of the present disclosure, a spiral angle of the worm gear is β ; and β satisfies: $30^\circ \leq \beta \leq 40^\circ$.

[0023] According to some embodiments of the present disclosure, the vehicle steering system further includes a coupling device. The coupling device includes the first steering shaft and the second steering shaft. The first steering shaft is connected to the steering gear. The first steering shaft is movable between a coupling position and a decoupling position. The first steering shaft is coupled to the second steering shaft at the coupling position and transmits the steering torque of the steering gear. The first steering shaft is decoupled from the second steering shaft at the decoupling position and disconnects the transmission of the steering torque of the steering gear.

[0024] According to some embodiments of the present disclosure, the coupling device further includes a third steering shaft. The first steering shaft is connected to the steering gear through the third steering shaft. The first steering shaft is engaged with the third steering shaft to transmit the steering torque of the steering gear. The first steering shaft is movable between the coupling position and the decoupling position relative to the third steering shaft.

[0025] According to some embodiments of the present disclosure, the coupling device further includes: a shaft sleeve, sleeved on the first steering shaft, where the shaft sleeve is axially fixed to the first steering shaft and rotatable relative to the first steering shaft; and a driving assembly, connected to the shaft sleeve, where the driving assembly is configured to drive the first steering shaft to move between the coupling position and the decoupling position through the shaft sleeve.

[0026] The vehicle in an embodiment of the present disclosure includes the vehicle steering system according to any of the above embodiments of the present disclosure.

[0027] Other aspects and advantages of the present disclosure will be given in the following description, some of which will become apparent from the following description or may be learned from practices of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The foregoing and/or additional aspects and advantages of the present disclosure will become apparent and comprehensible in the description of the embodiments made with reference to the following accompanying drawings.

[0029] FIG. 1 is a three-dimensional view of a vehicle steering system according to an embodiment of the present disclosure.

[0030] FIG. 2 is a three-dimensional view of the vehicle steering system shown in FIG. 1 from another perspective.

[0031] FIG. 3 is a schematic diagram showing engagement between a feeling simulator and a first steering shaft of a vehicle steering system according to an embodiment of the present disclosure.

[0032] FIG. 4 is a schematic diagram showing engagement between a feeling simulator and a first steering shaft of a vehicle steering system from another perspective according to an embodiment of the present disclosure.

[0033] FIG. 5 is an assembly schematic diagram of a first steering shaft and a driven member of a vehicle steering system according to an embodiment of the present disclosure.

[0034] FIG. 6 is a schematic structural diagram of a vehicle steering system according to an embodiment of the present disclosure.

[0035] FIG. 7 is a cross-sectional view taken along line A-A in FIG. 6.

[0036] FIG. 8 is another schematic structural diagram of a vehicle steering system according to an embodiment of the present disclosure.

[0037] FIG. 9 is a cross-sectional view taken along line B-B in FIG. 8.

[0038] FIG. 10 is a schematic structural diagram of a vehicle steering system according to some other embodiments of the present disclosure.

[0039] FIG. 11 is a schematic structural diagram of a coupling device of a vehicle steering system according to an embodiment of the present disclosure.

[0040] FIG. 12 is a schematic structural diagram of a coupling device of a vehicle steering system from another perspective according to an embodiment of the present disclosure.

[0041] FIG. 13 is a cross-sectional view of a coupling device of a vehicle steering system according to an embodiment of the present disclosure, where a second transmission shaft is located at a coupling position.

[0042] FIG. 14 is a cross-sectional view of a coupling device of a vehicle steering system according to an embodiment of the present disclosure, where a second transmission shaft is located at a decoupling position.

[0043] FIG. 15 is a schematic structural diagram of a coupling device of a vehicle steering system according to an embodiment of the present disclosure, where a second transmission shaft is located at a decoupling position.

[0044] FIG. 16 is a schematic structural diagram of a coupling device of a vehicle steering system according to an embodiment of the present disclosure, where a second transmission shaft is located at a coupling position.

[0045] FIG. 17 is a cross-sectional view of a coupling device of a vehicle steering system according to an embodiment of the present disclosure from another perspective, where a second transmission shaft is located at a coupling position.

[0046] FIG. 18 is a cross-sectional view of a coupling device of a vehicle steering system according to an embodiment of the present disclosure from another perspective, where a second transmission shaft is located at a decoupling position.

[0047] FIG. 19 is a schematic structural diagram of a second transmission shaft of a coupling device of a vehicle steering system according to an embodiment of the present disclosure.

[0048] REFERENCE NUMERALS:

100: Vehicle steering system;

1: Housing; 11: Body 12: Accommodating portion; 121: End cover;

2: Steering shaft; 3: Feeling simulator; 31: Feeling driver;

32: Driving member; 321: Connecting portion; 33: Driven member; 4: Support member.

First transmission shaft 100, Second transmission shaft 200, Spline groove 210, Shaft sleeve 300, Driving assembly 400, Driving device 430, Transmission mechanism 440, Output lead screw 441, Output nut 442, Connecting rod mechanism 450, First connecting rod 451, Second connecting

rod 452, Third connecting rod 453, Third transmission shaft 500, Cavity 510, and Housing 600.

DETAILED DESCRIPTION

[0049] The embodiments of the present disclosure are described in detail below, and the embodiments described with reference to accompanying drawings are exemplary.

[0050] A vehicle steering system 100 according to embodiments of the present disclosure is described below with reference to FIG. 1 to FIG. 9.

[0051] As shown in FIG. 1 to FIG. 4, the vehicle steering system 100 according to the embodiments of the present disclosure includes a housing 1, a first steering shaft 2, and a feeling simulator 3.

[0052] Specifically, the first steering shaft 2 is rotatably arranged in the housing 1, the first steering shaft 2 is configured to be coupled to a steering gear to transmit a steering torque, and the first steering shaft 2 is configured to be decoupled from the steering gear to interrupt the transmission of the steering torque. The feeling simulator 3 is connected to the first steering shaft 2. The feeling simulator 3 simulates a steering feeling during transmission of the steering torque by the first steering shaft 2 and the steering gear when the first steering shaft 2 and the steering gear interrupt the transmission of the steering torque.

[0053] For example, when a driver controls a steering wheel of a vehicle to drive the first steering shaft 2 to turn, the feeling simulator 3 can provide resistance to the first steering shaft 2, thereby simulating the control damping feeling during steering. When the driver controls a steering wheel of a vehicle to drive the first steering shaft 2 to restore, the feeling simulator 3 may provide a restoring torque for the first steering shaft 2, thereby simulating a restoring force. As a result, the feeling simulator 3 may be arranged to simulate the real steering feel such as

steering damping feeling, restoring force, and the like during transmission of the steering torque by the first steering shaft 2 and the steering gear when the first steering shaft 2 and the steering gear interrupt the transmission of the steering torque. When the vehicle steering system 100 is a steering-by-wire system, the driving safety of the driver can be effectively improved. When the vehicle steering system 100 is a driving simulation system such as a steering system of a game vehicle, the game experience can be improved and the authenticity of simulation is ensured.

[0054] Finally, it should be noted that, the "steering-by-wire system" is a vehicle steering system 100 that eliminates a conventional mechanical connection between a steering wheel and a steering vehicle wheel (in this case, the first steering shaft 2 and the steering gear interrupt the transmission of the steering torque), transmits a signal through a data bus, and acquires a feedback command from a steering control system.

[0055] In the vehicle steering system 100 according to the embodiments of the present disclosure, the feeling simulator 3 is arranged and the feeling simulator 3 simulates a steering feeling during transmission of the steering torque by the first steering shaft 2 and the steering gear when the first steering shaft 2 and the steering gear interrupt the transmission of the steering torque. When the vehicle has emerging functions such as an on-board multimedia function, a drive-by-wire function, and an autonomous driving function, the feeling simulator 3 can be configured to simulate steering feeling such as steering damping feeling and the restoring force, and ensure the authenticity of simulation and improve user experience.

[0056] In some embodiments of the present disclosure, referring to FIG. 3 and FIG. 4, the feeling simulator 3 includes a feeling driver 31, a driving member 32, and a driven member 33. Specifically, the feeling driver 31 has an output shaft. The feeling driver 31 is arranged on the housing 1. The driving member 32 is fixed to the output shaft. The driven member 33 is fixed to

the first steering shaft 2. The driven member 33 is engaged with the driving member 32.

[0057] As a result, since the driven member 33 is fixed to the first steering shaft 2, the driven member 33 rotates with the first steering shaft 2 when the first steering shaft 2 rotates. When the driver controls the steering wheel of the vehicle to drive the first steering shaft 2 and the driven member 33 to turn, the feeling driver 31 can drive the driving member 32 to rotate through the output shaft and provide a torque opposite to a rotation direction of the driven member 33, thereby providing resistance for the rotation of the driven member 33 for simulating the steering damping feeling. When the driver controls the steering wheel of the vehicle to drive the first steering shaft 2 and the driven member 33 to restore, the feeling driver 31 can drive the driving member 32 to rotate and provide the same torque as the rotation direction of the driven member 33, thereby providing assistance for the rotation of the driven member 33 for simulating the restoring force. Moreover, when the feeling driver 31 alternately rotates forward and backward at a high frequency, a function of vibration prompt can be realized. In addition, while ensuring the authenticity of the simulation, the structure of the feeling simulator 3 is simple and easy to implement. The feeling driver 31 may be a feeling motor. However, the feeling driver is not limited thereto.

[0058] In some embodiments of the present disclosure, the vehicle steering system 100 further includes a rotation angle detector (not shown) and a controller (not shown). The rotation angle detector is configured to detect a rotation direction of the first steering shaft 2. The controller is configured to communicate with each of the rotation angle detector and the feeling driver 31. When the first steering shaft 2 turns, the controller controls the feeling driver 31 to provide resistance against the turning of the first steering shaft 2. When the first steering shaft 2 restores, the controller controls the feeling driver 31 to provide assistance for the restoring of the

first steering shaft 2.

[0059] For example, when the rotation angle detector detects a steering signal, the rotation angle detector transmits the detected steering signal to the controller, and the controller controls the feeling driver 31 to rotate according to the received steering signal. In this case, the feeling driver 31 drives the driving member 32 to rotate and causes the driving member 32 to provide a torque opposite to the rotation direction of the driven member 33 and the rotation direction of the first steering shaft 2, thereby providing resistance for the rotation of the first steering shaft 2, so as to simulate the steering damping feeling during transmission of the steering torque by the first steering shaft 2 and the steering gear. For example, when the rotation angle detector detects a restoring signal, the rotation angle detector transmits the detected restoring signal to the controller, and the controller controls the feeling driver 31 to rotate according to the received restoring signal. In this case, the feeling driver 31 drives the driving member 32 to rotate and causes the driving member 32 to provide the same torque as the rotation direction of the driven member 33 and the rotation direction of the first steering shaft 2, thereby providing assistance for the restoring of the first steering shaft 2, so as to simulate the restoring force during transmission of the steering torque by the first steering shaft 2 and the steering gear. As a result, the rotation angle detector and the controller are arranged to simulate the steering damping feeling and the restoring force during transmission of the steering torque by the first steering shaft 2 and the steering gear when the first steering shaft 2 and the steering gear interrupt the transmission of the steering torque, thereby improving the authenticity and reliability of the simulation.

[0060] In some embodiments of the present disclosure, the vehicle steering system 100 further includes a torque detector (not shown in the figure). The torque detector is configured to

detect a driving condition of a vehicle and transmit a first torque signal. The controller is configured to communicate with each of the torque detector and the feeling driver 31, receive the first torque signal, and control, according to the first torque signal, the feeling driver 31 to provide the first steering shaft 2 with a road feel simulation torque that simulates a road feel torque transmitted by the first steering shaft 2 and the steering gear.

[0061] For example, when road conditions (such as a steep slope, a slope, a muddy road, a rocky road, or a pothole road, and the like) are different, the first torque signals received by the controller are different. Therefore, different road feel simulation torques can be provided to the first steering shaft 2. Since the first steering shaft 2 is usually connected to the steering wheel, the first steering shaft 2 can transmit the road feel simulation torque to the steering wheel, so as to clearly feedback the road condition of the vehicle. Therefore, by arranging the torque detector, the controller can control the feeling driver 31 to rotate according to the first torque signal detected by the torque detector and cause the feeling driver 31 to provide the road feel simulation torque to the first steering shaft 2, when the vehicle steering system 100 is the steering-by-wire system. In this way, the feedback force of the vehicle steering system 100 on the vehicle road can be simulated in real time, and the driving condition of the vehicle can be effectively fed back, providing the driver with a more real feeling of the road and improving the vehicle maneuverability.

[0062] In a further embodiment of the present disclosure, the vehicle steering system 100 further includes a driving computer. The driving computer is configured to communicate with the controller and detect a driving attitude of the vehicle and transmit a second torque signal to the controller. The controller is configured to control, according to the second torque signal, the feeling driver 31 to provide the first steering shaft 2 with the road feel simulation torque that

simulates the road feel torque transmitted by the first steering shaft 2 and the steering gear. The "driving attitude of the vehicle" refers to the attitude of the vehicle in a driving state. For example, under the influence of the external environment, the vehicle may experience sideslip, fishtailing, and other conditions, causing the center of gravity of the vehicle to continuously change, and the posture of the vehicle to constantly change as well. It should be noted that the driving computer is the vehicle controller.

[0063] For example, when the vehicle travels at a high speed, the controller can control the feeling driver 31 to rotate according to the second torque signal transmitted by the driving computer and cause the feeling driver 31 to provide a large torque for the first steering shaft 2 and the steering wheel, so as to increase a weight of the steering wheel and make the steering wheel more stable. When the vehicle travels at a low speed, the controller can control the feeling driver 31 to rotate according to the second torque signal transmitted by the driving computer and cause the feeling driver 31 to drive the steering wheel lighter through the first steering shaft 2, thereby causing the steering wheel easier to rotate. When the vehicle sideslips, the controller can control the feeling driver 31 to rotate according to the second torque signal transmitted by the driving computer and cause the feeling driver 31 to correct the steering wheel through the first steering shaft 2, so as to ensure the driving safety.

[0064] Therefore, by arranging the driving computer, the controller can control the feeling driver 31 to rotate according to the second torque signal provided by the driving computer and cause the feeling driver 31 to provide the road feel simulation torque to the first steering shaft 2 and the steering wheel, when the vehicle steering system 100 is the steering-by-wire system and the driving simulation system such as a steering system of a game vehicle. The driving attitude of the vehicle is effectively fed back, so that the feedback force of

the driving attitude of the vehicle to the vehicle steering system 100 can be simulated in real time, which provides the driver with a more real road feel and further improves the vehicle maneuverability.

[0065] In some embodiments of the present disclosure, the vehicle steering system 100 further includes a safety detector. The safety detector is configured to detect whether a driver drives safely. The controller is configured to communicate with each of the safety detector and the feeling driver 31. The controller controls the feeling driver 31 to provide a vibration force to drive the first steering shaft 2 to alternately rotate forward and backward when the safety detector detects a safety risk in the driving. In this way, the safety detector and the controller can be arranged to play a role of vibration warning when there is a safety risk in driving. In this way, the vibration feeling can be provided to the driver, which can effectively improve the driving safety.

[0066] Optionally, the safety detector includes at least one of a fatigue detector, a lane departure detector, a collision detector, a lane change blind area detector, and a reversing collision detector. For example, when the safety detector includes the fatigue detector, and the fatigue detector detects fatigue driving of the driver and transmits a detected fatigue signal to the controller, the controller controls, according to the received fatigue signal, the feeling driver 31 to alternately rotate forward and backward, so as to realize an effect of fatigue driving prompt, thereby reducing a risk of a traffic accident caused by the fatigue driving.

[0067] When the safety detector includes the lane departure detector, and the lane departure detector detects that the vehicle is about to deviate from the lane and transmits a detected lane departure warning signal to the controller, the controller can control, according to the received lane departure warning signal, the feeling driver 31 to alternately rotate forward and

backward, so that a lane departure warning can be realized, and the risk of the traffic accident caused by the lane deviation can be reduced.

[0068] When the safety detector includes the collision detector, and the collision detector detects that the vehicle is about to collide with other vehicles, pedestrians and obstacles, the collision detector transmits a collision warning signal to the controller. The controller can control, according to the received collision warning signal, the feeling driver 31 alternately rotate forward and backward, so that a collision warning can be realized and occurrence of the collision can be avoided.

[0069] When the safety detector includes the lane change blind area detector, since there is a blind area in a rearview mirror of the vehicle, the lane change blind area detector can detect an overtaking vehicle in the blind area of the rearview mirror and transmit a risk signal to the controller, and the controller can control, according to the received risk signal, the feeling driver 31 to alternately rotate forward and backward. In this way, the blind area prompt of the lane change can be realized to avoid the traffic accident due to the blind area in the process of the lane change.

[0070] When the safety detector includes the reversing collision detector, and the vehicle is in a dangerous distance between an obstacle and a vehicle when reversing, or when a pedestrian or a vehicle is suddenly near the rear of the vehicle during the process of reversing, the reversing collision detector transmits a reverse collision warning signal to the controller. The controller can control, according to the received collision warning signal, the feeling driver 31 alternately rotate forward and backward, so as to realize a reverse collision warning and avoid a safety accident during the reversing process.

[0071] Therefore, through the above arrangement, the vehicle steering system 100 can

realize at least one of the fatigue driving warning, the lane departure warning, the collision warning, the lane change blind area warning, and the reverse collision warning, thereby reducing the risk of traffic accident and effectively improving the driving safety. Certainly, the safety detector may also include other types of detectors, not limited to the fatigue detector, the lane departure detector, the collision detector, the lane change blind area detector, and the reversing collision detector.

[0072] In some embodiments of the present disclosure, with reference to FIG. 2 and FIG. 6, the housing 1 includes a body 11 and an accommodating portion 12. The first steering shaft 2 and the driven member 33 are arranged in the body 11. The accommodating portion 12 protrudes from an outer surface of the body 11. An interior of the accommodating portion 12 is in communication with an interior of the body 11. The driving member 32 is arranged in the accommodating portion 12. For example, in the example of FIG. 2 and FIG. 6, the accommodating portion 12 is connected to a radially outer side of the body 11, and a shape of the accommodating portion 12 is adapted to a shape of the driving member 32. Therefore, by arranging the body 11 and the accommodating portion 12, on one hand, the body 11 can effectively protect the first steering shaft 2 and the driven member 33, and the accommodating portion 12 can effectively protect the driving member 32, so that impurities such as the external dust can be prevented from entering the interior of the housing 1 and affecting the rotation of the first steering shaft 2, the driven member 33, and the driving member 32. On the other hand, occupied space of the accommodating portion 12 such arranged is small, and the structure of the entire vehicle steering system 100 can be made more compact, thereby reducing the occupied space of the vehicle steering system 100 in the vehicle, facilitating a spatial layout of other parts in the vehicle, and increasing movement space for the legs of the driver.

[0073] Optionally, a part of the driving member 32 extends into the body 11 and engages with the driven member 33. Such arrangement can ensure the reliability of the engagement between the driving member 32 and the driven member 33, so that the vehicle steering system 100 has functions such as steering damping feeling, road feeling feedback, steering restoring force, and vibration prompt. Moreover, since a part of the driving member 32 extends into the body 11, a radial dimension of the driven member 33 can be smaller, so that structural compactness of the vehicle steering system 100 can be further improved, and the occupied space of the entire vehicle steering system 100 can be reduced.

[0074] In some specific embodiments of the present disclosure, referring to FIG. 2 to FIG. 4, a free end of the output shaft extends into the accommodating portion 12 from one end of the accommodating portion 12 (for example, a left end in FIG. 2) and is fixed to one end of the driving member 32 (for example, a left end in FIG. 4). A support member 4 is arranged in the other end of the accommodating portion 12 (for example, a right end in FIG. 2), and the other end of the driving member 32 (for example, a right end in FIG. 4) rotatably extends through the support member 4.

[0075] For example, in the examples of FIG. 3 and FIG. 4, one end of the driving member 32 away from the feeling driver 31 may be provided with a connecting portion 321. A diameter of the connecting portion 321 is smaller than a diameter of the driving member 32. A through fitting hole may be formed on the support member 4, and the connecting portion 321 fits in the fitting hole. A diameter of the fitting hole is greater than the diameter of the connecting portion 321 and smaller than the diameter of the driving member 32. In this way, when the support member 4 is fixed to the accommodating portion 12, radial movement of the connecting portion 321 relative to the support member 4 may be limited, and axial movement of the driving

member 32 relative to the support member 4 may be limited. As a result, by arranging the support member 4, one end of the driving member 32 away from the feeling driver 31 may be supported on the support member 4, so that the rotation of the driving member 32 can be more stable, thereby improving the fitting stability between the driving member 32 and the driven member 33.

[0076] Optionally, as shown in FIG. 2 to FIG. 4, the other end (such as, a right end in FIG. 2) of the accommodating portion 12 is open, and the other end (such as, the right end in FIG. 2) of the accommodating portion 12 is provided with a detachable end cover 121. In this way, the end cover 121 has better stopping and limiting effects, and an axial positioning of the support member 4 can be realized, thereby further ensuring rotational stability of the driving member 32. Moreover, the end cover 121 can ensure the tightness of the housing 1, and prevent impurities such as external dust from entering the housing 1 through the other end of the accommodating portion 12 and affecting an operation of the driving member 32 and the driven member 33, so that reliability of the engagement between the driving member 32 and the driven member 33 can be guaranteed. In addition, when the support member 4 is mounted, the support member 4 can be extended from the open end of the accommodating portion 12 into the accommodating portion 12 and the driving member 32 can be sleeved on the support member 4, and finally the end cover 121 can be mounted to the accommodating portion 12. When the support member 4 is disassembled, simply remove the end cover 121, and then take out the support member 4 from the open end of the accommodating portion 12, so that the mounting and disassembly of the support member 4 are more convenient, and the replacement of the support member 4 is convenient.

[0077] Optionally, referring to FIG. 2 and FIG. 6, a central axis of the accommodating

portion 12 is perpendicular to a central axis of the body 11. For example, with reference to FIG. 2 and FIG. 6, the driven member 33 is sleeved on the first steering shaft 2, and the body 11 and the driven member 33 are arranged coaxially with the first steering shaft 2. The driving member 32 is arranged coaxially with the accommodating portion 12, and the driving member 32 and the accommodating portion 12 extend in a radial direction of the first steering shaft 2. In this way, the structure of the entire housing 1 is simple, the processing is convenient, and the arrangement of the feeling driver 31, the driving member 32, and the driven member 33 is convenient. Further, the driving member 32 located in the accommodating portion 12 and the driven member 33 located in the body 11 can be better engaged to ensure that the feel of the vehicle driving can be more realistically simulated.

[0078] In some optional embodiments of the present disclosure, with reference to FIG. 2, the accommodating portion 12 and the body 11 may be formed in one piece. In this way, impurities such as the dust can be avoided from entering an interior of the housing 1 due to a gap generated at a connection between the accommodating portion 12 and the body 11, so as to effectively improve the tightness of the entire housing 1, ensure the normal operation of the driving member 32 and the driven member 33, and improve the reliability of the vehicle steering system 100 to simulate the driving feel. Moreover, the accommodating portion 12 and the housing 1 can be connected without other parts, so that a quantity of parts of the entire vehicle steering system 100 can be reduced, the structure of the vehicle steering system 100 can be made simpler, and a cost can be reduced. In addition, by integrally forming the accommodating portion 12 and the body 11, the integrity of the entire vehicle steering system 100 can be improved, the vehicle steering system 100 and the mounting and disassembly are more convenient, and the assembly and disassembly efficiency can be effectively improved.

[0079] Optionally, as shown in FIG. 2 to FIG. 4, the feeling driver 31 is detachably connected to the accommodating portion 12. In this way, the mounting and disassembly between the feeling driver 31 and the accommodating portion 12 are more convenient. When maintaining or replacing the feeling driver 31, the feeling driver 31 is merely required to be removed from the accommodating portion 12. The operation is more convenient and can improve the efficiency of maintenance and replacement. For example, in the example of FIG. 2 to FIG. 4, the feeling driver 31 and the accommodating portion 12 are connected by a threaded fastener such as a screw, so that a secure connection between the feeling driver 31 and the accommodating portion 12 can be realized, and the cost is low. Certainly, the feeling driver 31 and the accommodating portion 12 can also be detachably connected by other means, such as a snap structure. It may be understood that a connection manner between the feeling driver 31 and the accommodating portion 12 can be specifically determined according to an actual need to better meet a practical application.

[0080] In some optional embodiments of the present disclosure, referring to FIG. 3 and FIG. 4, the driving member 32 is a worm and the driven member 33 is a worm gear meshed with the worm. In this way, the worm gear is meshed with the worm, so that the transmission is more stable and reliable while ensuring that the real feeling during vehicle driving can be effectively simulated, thereby reducing the noise of the vehicle steering system 100. In addition, the worm gear and the worm are compact in structure, which can effectively save the space occupied by the vehicle steering system 100.

[0081] Further, optionally, a spiral angle of the worm gear is β , where β satisfies: $30^\circ \leq \beta \leq 40^\circ$. Through the arrangement, a worm gear and worm mechanism may be a mechanism without the self-locking function, so that the worm can rotate clockwise under the drive of the

output shaft of the feeling driver 31, and may also rotate counterclockwise under the drive of the output shaft. Therefore, a resistance can be provided when the first steering shaft 2 drives the worm gear to turn, so as to simulate the steering damping feeling, and assistance can be provided when the first steering shaft 2 drives the worm gear to restore, so as to simulate the restoring force. In this way, the structure is more reliable.

[0082] Certainly, the present disclosure is not limited thereto. In some other optional embodiments of the present disclosure, the driving member 32 and the driven member 33 may also be helical gears meshing with each other (not shown in the figure). As a result, the real feel of the vehicle driving can also be effectively simulated, the structure is compact, the transmission is relatively accurate, the transmission efficiency is high, the operation is reliable, and the service life is long.

[0083] In the vehicle steering system 100 according to the embodiments of the present disclosure, when the vehicle steering system 100 is the steering-by-wire system, the driving simulation system, and the like, the feeling driver 31 can drive the output shaft to drive the driving member 32 to rotate and provide the torque for the driven member 33 to simulate the real driving feel such as the steering damping, the restoring force and the road feel simulation torque. The structure is simple and the operation is convenient. Moreover, the torque detector and the driving computer can be arranged to detect the driving condition and the driving attitude of the vehicle. Therefore, the feedback force of the vehicle steering system 100 by the driving condition and the driving attitude of the vehicle can be simulated, so as to provide the driver with a more realistic road feeling. In this way, the safety detector can be arranged to play a role of vibration warning when there is a safety risk in driving. In this way, the vibration feeling can be provided to the driver and at least one of the fatigue driving warning, the lane departure warning, the

collision warning, the lane change blind area warning, and the reverse collision warning can be realized, which can effectively improve the driving safety. Besides, the structure of the entire vehicle steering system 100 is compact and delicate, which can effectively improve the assembly and disassembly efficiency, and has good sealing performance, which can prevent the impurities such as the dust from entering the interior of the housing 1. Therefore, the normal operation of the driving member 32 and the driven member 33 can be guaranteed, which has high reliability.

[0084] According to some specific embodiments of the present disclosure, as shown in FIG. 13, FIG. 14, FIG. 17, and FIG. 18, the vehicle steering system 100 further includes a coupling device 10. The coupling device 10 includes a second steering shaft 101 and a first steering shaft 2. The first steering shaft 2 is connected to the steering gear. The first steering shaft 2 is movable between a coupling position and a decoupling position. The first steering shaft 2 combines with the second steering shaft 101 at the coupling position and transmits a steering torque of the steering gear. In this case, the synchronous rotation between the second steering shaft 101 and the first steering shaft 2 can be realized, as shown in FIG. 13 and FIG. 17. The first steering shaft 2 is decoupled from the second steering shaft 101 at the decoupling position and the transmission of the steering torque of the steering gear is disconnected. In this case, the second steering shaft 101 and the first steering shaft 2 can be rotated separately, as shown in FIG. 17 and FIG. 18. The feeling simulator 3 is connected to the first steering shaft 2. A feeling simulator 200 simulates the feel of the first steering shaft 2 at the coupling position when the first steering shaft 2 is at the decoupling position.

[0085] By dividing the coupling device 10 into the second steering shaft 101 and the first steering shaft 2, and the first steering shaft 2 is connected to the steering gear, the second steering shaft 101 can be connected to the wheel. When the second steering shaft 101 contacts

the first steering shaft 2, the synchronous movement of the steering gear and the wheel can be realized. When the second steering shaft 101 and the first steering shaft 2 are decoupled, the steering gear and the wheel can be moved separately. By connecting the feeling simulator 3 with the first steering shaft 2, the first steering shaft 2 can transfer the force of the feeling simulator 3 to the steering gear. In this way, the structure of the coupling device 10 is more reasonable.

[0086] According to some specific embodiments of the present disclosure, as shown in FIG. 15, FIG. 16, and FIG. 19, the coupling device 10 further includes a third transmission shaft 500. The first steering shaft 2 is connected to the steering gear through the third transmission shaft 500. The first steering shaft 2 is engaged with the third transmission shaft 500 to transmit the steering torque of the steering gear, and the first steering shaft 2 can move between the coupling position and the decoupling position relative to the third transmission shaft 500.

[0087] Therefore, the first steering shaft 2 can be rotated synchronously with the steering gear through the third transmission shaft 500. When the first steering shaft 2 moves between the coupling position and the decoupling position, the position of the steering gear remains unchanged, which improves a fixed position of the steering gear held by a passenger and optimizes the driving experience.

[0088] In some embodiments of the present disclosure, the third transmission shaft 500 is configured with a cavity 510. The first steering shaft 2 extends into the cavity 510. An inner peripheral surface of the third transmission shaft 500 is configured with multiple splines. Each spline extends along an axial direction of the third transmission shaft 500, and the multiple splines are arranged along the circumferential direction of the third transmission shaft 500. An outer peripheral surface of the first steering shaft 2 is configured with multiple spline grooves 210. Each spline groove 210 extends in the axial direction of the first steering shaft 2, and the

multiple spline grooves 210 are arranged in a circumferential direction of the first steering shaft 2. The multiple splines engage with the multiple spline grooves 210. In this way, while facilitating the function of transmitting the steering torque between the first steering shaft 2 and the third transmission shaft 500, a relative sliding between the first steering shaft 2 and the third transmission shaft 500 along the axial direction of the first steering shaft 2 (that is, the axial direction of the third transmission shaft 500) is also facilitated.

[0089] According to some specific embodiments of the present disclosure, as shown in FIG. 10, FIG. 13 and FIG. 14, the coupling device 10 further includes a shaft sleeve 300 and a driving assembly 400. The shaft sleeve 300 is sleeved on the first steering shaft 2. The shaft sleeve 300 is axially fixed to the first steering shaft 2 and rotatable relative to the first steering shaft 2. The driving assembly 400 is connected to the shaft sleeve 300. The driving assembly 400 drives the first steering shaft 2 to move between the coupling position and the decoupling position through the shaft sleeve 300. In this way, the driving assembly 400 can provide a driving force for the first steering shaft 2, so as to facilitate the movement of the first steering shaft 2. A direct contact is not required between the first steering shaft 2 and the driving assembly 400 by arranging the shaft sleeve 300. When the first steering shaft 2 can be displaced along the axis, it also ensures that the first steering shaft 2 can rotate relative to the driving assembly 400. That is to say, the presence of the driving assembly 400 does not interfere with the rotation of the first steering shaft 2.

[0090] According to some specific embodiments of the present disclosure, as shown in FIG. 15, FIG. 16, and FIG. 19, at least a part of the second steering shaft 101, at least a part of the first steering shaft 2 and the shaft sleeve 300 are arranged in the housing 1. For example, a part of the second steering shaft 101, a part of the first steering shaft 2, a part of the shaft sleeve

300, and a part of the third transmission shaft 500 are located in the housing 1. The driving assembly 400 is mounted outside the housing 1.

[0091] By arranging the housing 1, on one hand, a mounting position is provided for the driving assembly 400, and on the other hand, a direct contact area between the second steering shaft 101, the first steering shaft 2, and the shaft sleeve 300 and the outside world can be reduced, and the damage probability of the second steering shaft 101, the first steering shaft 2, and the shaft sleeve 300 can be reduced.

[0092] According to some specific embodiments of the present disclosure, as shown in FIG. 17 and FIG. 18, the driving assembly 400 includes a driving device 430, a transmission mechanism 440, and a connecting rod mechanism 450. The driving device 430 is hinged to the housing 1. The transmission mechanism 440 is drive-connected to the driving device 430. The connecting rod mechanism 450 is hinged to each of the transmission mechanism 440, the housing 1, and the shaft sleeve 300.

[0093] In this way, a structure of the driving assembly 400 is reasonable, which is convenient for the transmission of the driving force, and the driving assembly 400 is arranged separately, which reduces difficulty of production. The connecting rod is configured to drive the shaft sleeve 300 and the first steering shaft 2, which not only makes the force transmission more reliable and labor-saving, but also facilitates the elimination of the turning torque of the shaft sleeve 300 and ensures that the shaft sleeve 300 can continue to move linearly.

[0094] By arranging the connecting rod mechanism 450, while realizing the transmission of the driving force between the driving device 430 and the first steering shaft 2, the connecting rod mechanism 450 can increase the force driving the movement of the first steering shaft 2. Therefore, the requirement for the driving force outputted by the driving device 430 can

be reduced, thereby reducing the cost of the driving device 430. Moreover, the connecting rod mechanism 450 can expand movement stroke of the first steering shaft 2, and can realize a long-distance transmission of the driving force between the driving device 430 and the first steering shaft 2. By using diversity of the transmission direction of the connecting rod mechanism 450, the shaft sleeve 300 and the first steering shaft 2 can be driven to move according to a predetermined path while reducing a position requirement of the driving device 430 and improving flexibility of a layout of the driving device 430.

[0095] According to some specific embodiments of the present disclosure, as shown in FIG. 17 to FIG. 18, the connecting rod mechanism 450 includes a first connecting rod 451, a second connecting rod 452, and a third connecting rod 453. One end of the first connecting rod 451 is hinged to the transmission mechanism 440, and the other end of the first connecting rod 451 is hinged to the shaft sleeve 300. One end of the second connecting rod 452 is hinged to the transmission mechanism 440, and the other end of the second connecting rod 452 is hinged to the shaft sleeve 300. In this way, the connecting rod mechanism 450 can drive the shaft sleeve 300 through two paths, and the driving force of the connecting rod mechanism 450 to the shaft sleeve 300 is more dispersed, thereby improving the stability of the movement of the shaft sleeve 300.

[0096] Moreover, one end of the third connecting rod 453 is hinged to the housing 1, and the other end of the third connecting rod 453 is hinged to the first connecting rod 451 and the second connecting rod 452. In this way, a relative position between the first connecting rod 451 and the second connecting rod 452 is stable, and the two ends of the first connecting rod 451 and the two ends of the second connecting rod 452 can swing with the third connecting rod 453 as a fulcrum.

[0097] The vehicle (not shown in the figure) according to an embodiment of the

present disclosure includes the vehicle steering system 100 according to any of the above embodiments of the present disclosure.

[0098] The vehicle according to an embodiment of the present disclosure, by adopting the vehicle steering system 100, it can be configured to simulate the real driving feel such as the steering damping feeling and the restoring force, and functions such as the road feeling feedback and the vibration prompt can also be realized, so as to ensure the authenticity of the simulation.

[0099] Other configurations and operations of the vehicle according to the embodiments of the present disclosure are known to those of ordinary skill in the art and will not be described in detail herein.

[0100] In the description of the present disclosure, it should be understood that orientation or position relationships indicated by the terms such as "center", "longitudinal", "transverse", "length", "width", "thickness", "on", "below", "front", "back", "left", "right", "vertical", "horizontal", "top", "bottom", "inside", "outside", "clockwise", "anticlockwise", "axial direction", "radial direction", and "circumferential direction" are based on orientation or position relationships shown in the accompanying drawings, and are used only for ease and brevity of illustration and description, rather than indicating or implying that the mentioned apparatus or component must have a particular orientation or must be constructed and operated in a particular orientation. Therefore, such terms should not be construed as limiting of the present disclosure.

[0101] In the descriptions of the present disclosure, descriptions using reference terms "an embodiment", "some embodiments", "an exemplary embodiment", "an example", "a specific example", or "some examples" mean that specific characteristics, structures, materials, or features described with reference to the embodiment or example are included in at least one embodiment or example of the present disclosure. In the present disclosure, exemplary

descriptions of the foregoing terms do not necessarily refer to the same embodiment or example.

[0102] Although the embodiments of the present disclosure have been shown and described, a person of ordinary skill in the art should understand that various changes, modifications, replacements, and variations may be made to the embodiments without departing from the principles and spirit of the present disclosure, and the scope of the present disclosure is as defined by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A vehicle steering system, comprising:

a housing;

a first steering shaft, rotatably arranged in the housing, wherein the first steering shaft is configured to be coupled to a steering gear to transmit a steering torque; the first steering shaft is configured to be decoupled from the steering gear to interrupt the transmission of the steering torque; and

a feeling simulator, connected to the first steering shaft, wherein the feeling simulator is configured to simulate a steering feeling during the transmission of the steering torque by the first steering shaft and the steering gear when the first steering shaft and the steering gear interrupt the transmission of the steering torque.

2. The vehicle steering system according to claim 1, wherein the feeling simulator comprises:

a feeling driver, having an output shaft and arranged on the housing;

a driving member, fixed on the output shaft; and

a driven member, fixed on the first steering shaft and engaged with the driving member.

3. The vehicle steering system according to claim 2, further comprising:

a rotation angle detector, configured to detect a rotation direction of the first steering shaft;

and

a controller, configured to communicate with each of the rotation angle detector and the feeling driver, wherein

when the first steering shaft turns, the controller controls the feeling driver to provide

resistance against the turning of the first steering shaft; and

when the first steering shaft restores, the controller controls the feeling driver to provide assistance to the restoring of the first steering shaft.

4. The vehicle steering system according to claim 2 or 3, further comprising:

a torque detector, configured to detect a driving condition of a vehicle and transmit a first torque signal; and

a controller, configured to communicate with each of the torque detector and the feeling driver, receive the first torque signal, and control, according to the first torque signal, the feeling driver to provide the first steering shaft with a road feel simulation torque that simulates a road feel torque transmitted by the first steering shaft and the steering gear.

5. The vehicle steering system according to claim 4, further comprising:

a driving computer, configured to communicate with the controller and detect a driving attitude of the vehicle and transmit a second torque signal to the controller, wherein the controller is configured to control, according to the second torque signal, the feeling driver to provide the first steering shaft with the road feel simulation torque that simulates the road feel torque transmitted by the first steering shaft and the steering gear.

6. The vehicle steering system according to any of claims 2 to 5, further comprising:

a safety detector, configured to detect whether a driver drives safely; and

a controller, configured to communicate with each of the safety detector and the feeling driver, wherein

the controller controls the feeling driver to provide a vibration force to drive the first steering shaft to alternately rotate forward and backward when the safety detector detects a safety risk in the driving.

7. The vehicle steering system according to claim 6, wherein the safety detector comprises at least one of a fatigue detector, a lane departure detector, a collision detector, a lane change blind area detector, and a reversing collision detector.

8. The vehicle steering system according to any of claims 2 to 7, wherein the housing comprises:

a body, wherein the first steering shaft and the driven member are both arranged in the body;
and

an accommodating portion, protruding from an outer surface of the body, wherein an interior of the accommodating portion is in communication with an interior of the body; and the driving member is arranged in the accommodating portion.

9. The vehicle steering system according to claim 8, wherein a part of the driving member extends into the body and is engaged with the driven member.

10. The vehicle steering system according to claim 8, wherein a free end of the output shaft extends into the accommodating portion from one end of the accommodating portion and is fixed to one end of the driving member; a support member is arranged on the other end of the accommodating portion; and the other end of the driving member rotatably extends through the

support member.

11. The vehicle steering system according to claim 10, wherein the other end of the accommodating portion is open; and the other end of the accommodating portion is provided with a detachable end cover.

12. The vehicle steering system according to any of claims 8 to 11, wherein a central axis of the accommodating portion is perpendicular to a central axis of the body.

13. The vehicle steering system according to any of claims 8 to 12, wherein the accommodating portion and the body are formed in one piece.

14. The vehicle steering system according to any of claims 8 to 13, wherein the feeling driver is detachably connected to the accommodating portion.

15. The vehicle steering system according to any of claims 2 to 14, wherein the driving member is a worm; and the driven member is a worm gear meshed with the worm.

16. The vehicle steering system according to claim 15, wherein a spiral angle of the worm gear is β ; and β satisfies: $30^\circ \leq \beta \leq 40^\circ$.

17. The vehicle steering system according to any of claims 1 to 16, further comprising a coupling device, wherein the coupling device comprises the first steering shaft and the second

steering shaft; the first steering shaft is connected to the steering gear; the first steering shaft is movable between a coupling position and a decoupling position; the first steering shaft is coupled to the second steering shaft at the coupling position and transmits the steering torque of the steering gear; and the first steering shaft is decoupled from the second steering shaft at the decoupling position and disconnects the transmission of the steering torque of the steering gear.

18. The vehicle steering system according to claim 17, wherein the coupling device further comprises a third steering shaft; the first steering shaft is connected to the steering gear through the third steering shaft; the first steering shaft is engaged with the third steering shaft to transmit the steering torque of the steering gear; and the first steering shaft is movable between the coupling position and the decoupling position relative to the third steering shaft.

19. The vehicle steering system according to claim 17, wherein the coupling device further comprises:

a shaft sleeve, sleeved on the first steering shaft, wherein the shaft sleeve is axially fixed to the first steering shaft and rotatable relative to the first steering shaft; and

a driving assembly, connected to the shaft sleeve, wherein the driving assembly is configured to drive the first steering shaft to move between the coupling position and the decoupling position through the shaft sleeve.

20. A vehicle, comprising the vehicle steering system according to any of claims 1 to 19.