



(51) International Patent Classification:

B62D 5/00 (2006.01)

(21) International Application Number:

PCT/JP2020/009971

(22) International Filing Date:

09 March 2020 (09.03.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicants: **HONDA MOTOR CO., LTD.** [JP/JP]; 1-1, Minami-Aoyama 2-chome, Minato-ku, Tokyo, 1078556 (JP). **THYSSENKRUPP PRESTA AKTIENGESSELLSCHAFT** [LI/LI]; Essanestrasse 10, Eschen, 9492 (LI).

(72) Inventors: **WATANABE Yoshinobu**; c/o HONDA R&D CO., LTD., 4-1 Chuo 1-chome, Wako-shi Saitama, 3510193 (JP). **MIYAKAWA Hayato**; c/o HONDA R&D CO., LTD., 4-1 Chuo 1-chome, Wako-shi Saitama, 3510193 (JP). **HANJI Munetsugu**; c/o HONDA R&D CO., LTD., 4-1 Chuo 1-chome, Wako-shi Saitama, 3510193 (JP). **YAMAGUCHI Takaya**; c/o HONDA R&D CO., LTD., 4-1 Chuo 1-chome, Wako-shi Saitama, 3510193 (JP). **ARANYI Miklos**; Santisstrasse 31, Rebstein, 9445 (CH). **BERES Adela**; Fejer Lipot u. 65, Budapest, 1119 (HU). **DOMBAI Laszlo**; Muskotaly u. 17, Erd, 2030 (HU).

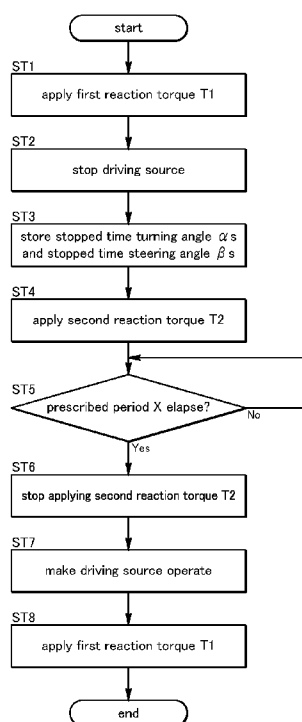
KAKAS Peter; Frankhegy utca 1. 1/2, Budapest, 1118 (HU).

(74) Agent: **OSHIMA & PARTNERS**; 2-20, Kanda-Jimbocho, Chiyoda-ku, Tokyo, 1010051 (JP).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: VEHICLE STEERING SYSTEM



(57) Abstract: To prevent a driver from feeling uncomfortable when the driver touches a steering member in a state where a driving source is stopped, a vehicle steering system (1) is provided in a vehicle (2) that travels by a driving force generated by a driving source (51). The vehicle steering system (1) includes; a steering member (10) configured to accept a steering operation; and a reaction force actuator (13) configured to apply a reaction force to the steering member (10) in response to the steering operation. In a state where the driving source (51) is stopped, the reaction force actuator (13) is configured to apply the reaction force to the steering member (10) based on a stopped time position that is a position of the steering member (10) at a time when the driving source (51) is stopped.

Published:

— *with international search report (Art. 21(3))*

Description

Title of Invention: VEHICLE STEERING SYSTEM

Technical Field

[0001] The present invention relates to a vehicle steering system.

Background Art

[0002] A known steer-by-wire vehicle steering system includes a steering member such as a steering wheel operated by a driver and a turning mechanism mechanically separated from the steering member and configured to change a turning angle of wheels. For example, there is a steer-by-wire steering system that executes control to make a turning angle of wheels coincide with an actual rotational position of a steering wheel in a state where an engine is stopped (see Japanese Unexamined Patent Application Publication No. JP 2006-321434A).

[0003] However, if the above control is executed in the state where the engine is stopped, the steering wheel may be rotated in a direction unintended by the driver, or a reaction force in the direction unintended by the driver may be applied to the steering wheel. If such situations are created, the driver may feel uncomfortable in a case where the driver touches the steering wheel when getting on and out of the vehicle.

[0004] In view of such a problem of the prior art, a primary object of the present invention is to provide a steering control system that can prevent a driver from feeling uncomfortable when the driver touches a steering member in a state where a driving source is stopped.

Summary of Invention

[0005] To achieve such an object, one embodiment of the present invention provides a vehicle steering system (1) provided in a vehicle (2) that travels by a driving force generated by a driving source (51), including; a steering member (10) configured to accept a steering operation; and a reaction force actuator (13) configured to apply a reaction force to the steering member in response to the steering operation, wherein in a state where the driving source is stopped, the reaction force actuator is configured to apply the reaction force to the steering member based on a stopped time position that is a position of the steering member at a time when the driving source is stopped.

[0006] According to this arrangement, it is possible to prevent the steering member from being moved in a direction unintended by the driver and to prevent a reaction force in the direction unintended by the driver from being applied to the steering member, in the state where the driving source is stopped. Therefore, it is possible to prevent the driver from feeling uncomfortable in a case where the driver touches the steering member when getting on and out of the vehicle.

- [0007] Preferably, in the state where the driving source is stopped, the reaction force actuator is configured to change the reaction force applied to the steering member based on displacement of the steering member with respect to the stopped time position.
- [0008] According to this arrangement, in the state where the driving source is stopped, an appropriate reaction force according to the displacement of the steering member with respect to the stopped time position can be applied to the steering member. Therefore, it is possible to more effectively prevent the driver from feeling uncomfortable in the case where the driver touches the steering member when getting on and out of the vehicle.
- [0009] Preferably, in the state where the driving source is stopped, the reaction force actuator is configured to stop applying the reaction force to the steering member after applying the reaction force to the steering member for a prescribed period.
- [0010] According to this arrangement, the operation time of the reaction force actuator can be reduced in the state where the driving source is stopped, so that power consumption of the vehicle steering system can be suppressed.
- [0011] Preferably, a maximum value of the reaction force that the reaction force actuator applies to the steering member in the state where the driving source is stopped is smaller than a maximum value of the reaction force that the reaction force actuator applies to the steering member in a state where the driving source is operating.
- [0012] According to this arrangement, electric power necessary for the operation of the reaction force actuator can be reduced in the state where the driving source is stopped, so that the power consumption of the vehicle steering system can be suppressed.
- [0013] Preferably, when the driving source starts to operate, the reaction force actuator is configured to apply the reaction force to the steering member based on a prescribed neutral position of the steering member in a last operation period of the driving source.
- [0014] According to this arrangement, when the driving source starts operating, the reaction force applied to the steering member can be shifted from the reaction force based on the stopped time position to the reaction force based on the neutral position. Therefore, it is possible to prevent the driver from feeling uncomfortable when the driver performs a steering operation on the steering member in a state where the driving source is operating.
- [0015] Preferably, in the state where the driving source is stopped, the reaction force actuator is configured to apply the reaction force to the steering member such that the steering member is restored to the stopped time position.
- [0016] According to this arrangement, the steering member can be restored to the stopped time position even if the driver touches the steering member to displace the steering member from the stopped time position in a state where the driving source is stopped.

Therefore, it is possible to more effectively prevent the driver from feeling uncomfortable.

[0017] Preferably, in a state where the driving source is operating, the reaction force actuator is configured to apply the reaction force to the steering member based on a prescribed neutral position of the steering member, and in a case where the driving source starts operating during restoration of the steering member to the stopped time position, the reaction force actuator is configured to apply the reaction force to the steering member based on the neutral position after the restoration of the steering member to the stopped time position is completed.

[0018] According to this arrangement, it is possible to apply the reaction force to the steering member based on the neutral position after the steering member is moved to a position where a turning angle of wheels matches a steering angle of the steering member. Thereby, it is possible to suppress a phase difference between the turning angle of the wheels and the steering angle of the steering member.

[0019] Preferably, in a case where the steering member accepts the steering operation during the restoration of the steering member to the stopped time position, the reaction force actuator is configured to stop the restoration of the steering member to the stopped time position and to shift the reaction force applied to the steering member from the reaction force based on the stopped time position to the reaction force based on the neutral position.

[0020] According to this arrangement, it is possible to shorten a period to complete the shift of the reaction force, compared with a case where the reaction force is shifted after the steering member is restored to the stopped time position.

[0021] Preferably, the steering member is rotatably provided on a vehicle body, and the reaction force actuator is configured to apply reaction torque to the steering member.

[0022] According to this arrangement, in the vehicle steering system provided with the rotatable steering member, it is possible to prevent the driver from feeling uncomfortable when the driver touches the steering member in the state where the driving source is stopped.

[0023] Preferably, the vehicle steering system further includes a turning mechanism (11) mechanically separated from the steering member and configured to change a turning angle of wheels (3).

[0024] According to this arrangement, in the steer-by-wire vehicle steering system, it is possible to prevent the driver from feeling uncomfortable when the driver touches the steering member in the state where the driving source is stopped.

Brief Description of Drawings

[0025] [fig.1]Figure 1 is a configuration diagram of a vehicle steering system according to an

embodiment of the present invention.

[fig.2A]Figure 2A is a graph showing a first control map.

[fig.2B]Figure 2B is a graph showing a second control map.

[fig.3]Figure 3 is a flow chart showing applying control of reaction torque.

[fig.4A]Figure 4A is a schematic diagram showing a first reaction torque applied in a state where the driving source is operating.

[fig.4B]Figure 4B is a schematic diagram showing a second reaction torque applied in a state where the driving source is stopped.

Description of Embodiments

[0026] An embodiment of a vehicle steering system 1 according to the present invention is described in the following. As shown in Figure 1, the vehicle steering system 1 consists of a steer-by-wire (SBW) steering system. A vehicle 2 provided with the vehicle steering system 1 is a four-wheeled vehicle including a pair of front wheels 3 and a pair of rear wheels (not shown in the drawings). Each front wheel 3 is supported by a vehicle body 8 (only an outline of a lower part thereof is shown in Figure 1) via a knuckle 7 so that a turning angle α can be changed, and thus serves as a wheel to be turned. The turning angle α is defined as an angle of each front wheel 3 with respect to a fore and aft direction in a plan view. The vehicle steering system 1 changes the turning angle α of each front wheel 3.

[0027] The vehicle steering system 1 includes a steering member 10 rotatably provided on the vehicle body 8, a turning mechanism 11 that turns the front wheels 3, a turning actuator 12 that drives the turning mechanism 11, a reaction force actuator 13 that applies a reaction torque T to the steering member 10, and a control unit 15 that controls the reaction force actuator 13 and the turning actuator 12. The vehicle steering system 1 may be provided with redundancy for an enhanced reliability. For instance, the vehicle steering system 1 may be provided with a plurality of turning actuators 12, a plurality of reaction force actuators 13, and/or a plurality of control units 15.

[0028] The steering member 10 accepts a steering operation by a driver. The steering member 10 includes a steering shaft 18 that is rotatably supported by the vehicle body 8, and a steering wheel 19 provided at an end of the steering shaft 18. The steering shaft 18 is rotatably supported by a steering column (not shown in the drawings) provided on the vehicle body 8, and the rear end thereof protrudes rearward from the steering column. The steering wheel 19 is connected to the rear end of the steering shaft 18 so as to rotate integrally with the steering shaft 18.

[0029] The reaction force actuator 13 consists of an electric motor, and is connected to the steering shaft 18 via a gear mechanism. When the reaction force actuator 13 is driven, a driving force thereof is transmitted to the steering shaft 18 as a rotational force. The

reaction force actuator 13 applies torque to the steering member 10 by rotating. The torque that the reaction force actuator 13 applies to the steering member 10 in response to the steering operation is defined as reaction torque T.

- [0030] The vehicle steering system 1 further includes a steering angle sensor 21 that detects a rotational angle of the steering shaft 18 around the central axial line thereof as a steering angle β . The steering angle sensor 21 may consist of a per se known rotary encoder. Further, the vehicle steering system 1 includes a torque sensor 22 that detects torque applied to the steering shaft 18 as steering torque. The torque sensor 22 detects the steering torque applied to a part of the steering shaft 18 located between the steering wheel 19 and the reaction force actuator 13. The steering torque is determined by operation torque applied to the steering wheel 19 by a driver and the reaction torque T applied to the steering shaft 18 by the reaction force actuator 13. The torque sensor 22 may consist of a per se known torque sensor such as a magnetostrictive torque sensor and a strain gauge. Also, the torque sensor 22 may estimate the steering torque based on the electric current flowing to the reaction force actuator 13.
- [0031] The vehicle steering system 1 further includes a first rotational angle sensor 23 that detects a rotational angle of the reaction force actuator 13. The first rotational angle sensor 23 may consist of a per se known resolver or rotary encoder.
- [0032] The turning mechanism 11 includes a rack shaft 26 extending laterally. The rack shaft 26 is supported by the vehicle body 8 so as to be movable in a lateral direction. The left and right ends of the rack shaft 26 are connected to the knuckles 7 via tie rods 30, and the knuckles 7 support the left and right front wheels 3, respectively. As the rack shaft 26 moves in the lateral direction, the turning angle α of each front wheel 3 changes. The turning mechanism 11 is mechanically separated from the steering member 10.
- [0033] The turning actuator 12 consists of an electric motor. The turning actuator 12 moves the rack shaft 26 in the lateral direction based on a signal from the control unit 15 so as to change the turning angle α of the left and right front wheels 3.
- [0034] The vehicle steering system 1 further includes a second rotational angle sensor 31 that detects a rotational angle of the turning actuator 12. The second rotational angle sensor 31 may consist of a per se known resolver or rotary encoder. In addition, the vehicle steering system 1 includes a turning angle sensor 32 that detects the turning angle α of the front wheels 3. In the present embodiment, the turning angle sensor 32 consists of a rack stroke sensor that detects a rack position or a position of the rack shaft 26 in the lateral direction, and detects the turning angle α of the front wheels 3 based on the rack position.
- [0035] The vehicle steering system 1 further includes a detection device 36 that detects the driver's input operation. The detection device 36 may include the torque sensor 22 and/

or the steering angle sensor 21 that detects the driver's steering operation. The detection device 36 may include a switch 37 that is operated by the driver. The switch 37 may consist of a mechanical switch provided on the vehicle body 8 or a function button displayed on a touch panel display.

- [0036] The control unit 15 is an electronic control device including a CPU, memory, a storage device storing a program, and the like. The control unit 15 is connected to the steering angle sensor 21, the torque sensor 22, the first rotational angle sensor 23, the second rotational angle sensor 31, and the turning angle sensor 32. Based on the signals from these sensors, the control unit 15 acquires signals corresponding to the steering angle β , the steering torque, the rotational angle of the reaction force actuator 13, the rotational angle of the turning actuator 12, and the turning angle α . In addition, the control unit 15 may be connected to a vehicle speed sensor, a yaw rate sensor, and a fore and aft acceleration sensor (not shown in the drawings) to acquire a vehicle speed, a yaw rate, a fore and aft acceleration, and the like.
- [0037] The control unit 15 is connected to the reaction force actuator 13 and the turning actuator 12 to control the reaction force actuator 13 and the turning actuator 12. The control unit 15 controls the turning actuator 12 so as to realize the turning angle α corresponding to at least one of the steering angle β and the steering torque, and controls the reaction force actuator 13 according to the turning angle α .
- [0038] With reference to Figure 1, the vehicle steering system 1 further includes a driving source 51 and a driving switch 52. The driving source 51 is a device that generates a driving force for driving the vehicle 2. The driving source 51 includes, for example, at least one of an internal combustion engine and an electric motor. The driving switch 52 is a switch that accepts a driving operation and a stop operation of the driving source 51. The driving switch 52 may consist of a mechanical switch provided on the vehicle body 8 or a function button displayed on a touch panel display.
- [0039] The control unit 15 is connected to the driving source 51 and the driving switch 52, and controls the driving source 51 in response to a signal from the driving switch 52. For example, when the driver performs the driving operation of the driving source 51 on the driving switch 52 in a state where the driving source 51 is stopped, the driving switch 52 accepts the driving operation of the driving source 51. Accordingly, the driving switch 52 sends a driving signal to the control unit 15. The control unit 15 makes the driving source 51 operate in response to the driving signal from the driving switch 52. Thereby, the driving source 51 generates the driving force, and the vehicle 2 can travel by the driving force. Hereinafter, the driving force generated by the driving source 51 is simply referred to as "the driving force".
- [0040] On the other hand, when the driver performs the stop operation of the driving source 51 on the driving switch 52 in a state where the driving source 51 is operating, the

driving switch 52 accepts the stop operation of the driving source 51. Accordingly, the driving switch 52 sends a stop signal to the control unit 15. The control unit 15 stops the driving source 51 in response to the stop signal from the driving switch 52.

[0041] The control unit 15 stores a first control map (see Figure 2A) and a second control map (see Figure 2B) as control maps of the reaction torque T (an example of a reaction force). The control unit 15 controls the reaction torque T based on the first control map in the state where the driving source 51 is operating. The control unit 15 controls the reaction torque T based on the second control map in the state where the driving source 51 is stopped.

[0042] Horizontal axes of the first and second control maps indicate the steering angle β (an example of a position of the steering member 10). Hereinafter, the steering angle β of 0 degree is referred to as a neutral steering angle β_n . The steering angle β larger than the neutral steering angle β_n is the steering angle β in a right turning direction, and the steering angle β smaller than the neutral steering angle β_n is the steering angle β in a left turning direction. Vertical axes of the first and second control maps indicate the reaction torque T . The reaction torque T larger than zero is the reaction torque T with respect to the right turning direction, and the reaction torque T smaller than zero is the reaction torque T with respect to the left turning direction. The dotted arrows shown in the first and second control maps indicate directions in which the steering angle β and the reaction torque T change.

[0043] In the first control map, a relationship between the steering angle β and the reaction torque T (hysteresis characteristic of the steering angle β and the reaction torque T) is defined based on the neutral steering angle β_n (an example of a neutral position). In the first control map, the reaction torque T changes from zero as the steering angle β changes from the neutral steering angle β_n . In the first control map, the reaction torque T changes based on displacement of the steering angle β with respect to the neutral steering angle β_n . Specifically, in the first control map, an absolute value of the reaction torque T increases as the displacement of the steering angle β with respect to the neutral steering angle β_n increases.

[0044] In the second control map, a relationship between the steering angle β and the reaction torque T (hysteresis characteristic of the steering angle β and the reaction torque T) is defined based on a stopped time steering angle β_s (an example of a stopped time position). The stopped time steering angle β_s is the steering angle β at a time when the driving source 51 is stopped. "a time when the driving source 51 is stopped" may be, for example, a time when the driving switch 52 accepts the stop operation of the driving source 51, a time when the driving source 51 starts to be stopped, or a time when the driving source 51 is completely stopped. In the second control map, the reaction torque T changes from zero as the steering angle β changes

from the stopped time steering angle β_s . In the second control map, the reaction torque T changes based on displacement of the steering angle β with respect to the stopped time steering angle β_s . Specifically, in the second control map, an absolute value of the reaction torque T increases as the displacement of the steering angle β with respect to the stopped time steering angle β_s increases. In the second control map, a changing rate (inclination) of the absolute value of the reaction torque T decreases as the displacement of the steering angle β with respect to the stopped time steering angle β_s increases. Therefore, in the second control map, the absolute value of the reaction torque T is substantially saturated in a region where the displacement of the steering angle β with respect to the stopped time steering angle β_s becomes maximum.

- [0045] The maximum value $M2$ of the absolute value of the reaction torque T in the second control map is smaller than the maximum value $M1$ of the absolute value of the reaction torque T in the first control map. A hysteresis width $W2$ (width of a hysteresis in a vertical axis direction) in the second control map is narrower than a hysteresis width $W1$ in the first control map.
- [0046] Next, an example of applying control of the reaction torque T is described with reference to Figure 3.
- [0047] The driving source 51 is operating at a start of the applying control of the reaction torque T . Therefore, the control unit 15 controls the reaction torque T based on the first control map (see Figure 2A), and the reaction force actuator 13 applies the reaction torque T based on the neutral steering angle β_n (hereinafter referred to as "the first reaction torque $T1$ ") to the steering member 10 (step ST1). As shown in Figure 4A, the reaction force actuator 13 changes the first reaction torque $T1$ applied to the steering member 10 based on displacement of the steering member 10 with respect to the neutral steering angle β_n (the current steering angle β_c - the neutral steering angle β_n). For example, the reaction force actuator 13 increases the first reaction torque $T1$ applied to the steering member 10 as the displacement of the steering member 10 with respect to the neutral steering angle β_n increases.
- [0048] When the driver performs the stop operation of the driving source 51 on the driving switch 52 in the state where the driving source 51 is operating as described above, the driving switch 52 accepts the stop operation of the driving source 51. The control unit 15 stops the driving source 51 in response to the stop signal from the driving switch 52 (step ST2).
- [0049] When the driving source 51 is stopped as described above, the control unit 15 acquires a stopped time turning angle α_s (the turning angle α at a time when the driving source 51 is stopped) based on a signal from the turning angle sensor 32, and stores the stopped time turning angle α_s . Further, the control unit 15 acquires the stopped time steering angle β_s (the steering angle β at a time when the driving source

51 is stopped) based on a signal from the steering angle sensor 21, and stores the stopped time steering angle β_s (step ST3).

[0050] When the driving source 51 is stopped as described above, the control unit 15 shifts the control map of the reaction torque T from the first control map (see Figure 2A) to the second control map (see Figure 2B). Therefore, the reaction force actuator 13 applies the reaction torque T based on the stopped time steering angle β_s (hereinafter referred to as "the second reaction torque T_2 ") to the steering member 10 (step ST4). As shown in Figure 4B, the reaction force actuator 13 changes the second reaction torque T_2 applied to the steering member 10 based on displacement of the steering member 10 with respect to the stopped time steering angle β_s (the current steering angle β_c - the stopped time steering angle β_s). For example, the reaction force actuator 13 increases the second reaction torque T_2 applied to the steering member 10 as the displacement of the steering member 10 with respect to the stopped time steering angle β_s increases. Further, the reaction force actuator 13 applies the second reaction torque T_2 to the steering member 10 such that the steering member 10 is restored to the stopped time steering angle β_s .

[0051] Incidentally, in step ST2, the driving switch 52 may accept the stop operation of the driving source 51 when the torque sensor 22 detects the steering operation. In this case, in step ST4, the reaction force actuator 13 may gradually shift the reaction torque T applied to the steering member 10 from the first reaction torque T_1 to the second reaction torque T_2 . Thereby, it is possible to suppress the driver from feeling uncomfortable due to a sudden change in the reaction torque T .

[0052] Next, the control unit 15 determines whether a prescribed period X has elapsed since the reaction force actuator 13 starts applying the second reaction torque T_2 to the steering member 10 in step ST4 (step ST5).

[0053] If determination in step ST5 is No, the control unit 15 repeats the determination in step ST5 until the determination in step ST5 becomes Yes. On the other hand, if the determination in step ST5 is Yes, the control unit 15 stops the reaction force actuator 13. Accordingly, the reaction force actuator 13 stops applying the second reaction torque T_2 to the steering member 10 (step ST6). Incidentally, the reaction force actuator 13 may resume applying the second reaction torque T_2 to the steering member 10 in a case where a boarding sensor 53 (see Figure 1) detects that the driver is about to get on or has got on the vehicle 2 after an end of step ST6 and before a start of step ST7. For example, the boarding sensor 53 may be a sensor that detects that a door of the vehicle 2 is unlocked, or may be a sensor that detects that the door of the vehicle 2 is opened. Also, the reaction force actuator 13 may apply the second reaction torque T_2 to the steering member 10 while the boarding sensor 53 detects that the door of the vehicle 2 is opened before step ST4 is started. Further, the reaction force actuator 13

may apply a third reaction torque T3, which is different from the second reaction torque T2, to the steering member 10 in a case where the boarding sensor 53 detects that the driver is about to get on or has got on the vehicle 2 or that the door of the vehicle 2 is opened. Preferably, the third reaction torque T3 may be larger than the second reaction torque T2.

[0054] When the driver performs the driving operation of the driving source 51 on the driving switch 52 in the state where the driving source 51 is stopped as described above, the driving switch 52 accepts the driving operation of the driving source 51. The control unit 15 makes the driving source 51 operate again in response to the driving signal from the driving switch 52 (step ST7).

[0055] In the state where the driving source 51 is operating as described above, the control unit 15 controls the reaction torque T based on the first control map (see Figure 2A). Therefore, the reaction force actuator 13 applies the first reaction torque T1 (the reaction torque T based on the neutral steering angle β_n) to the steering member 10 (step ST8). The neutral steering angle β_n in this step ST8 is the neutral steering angle β_n in a last operation period of the driving source 51 (for example, the neutral steering angle β_n when the driving source 51 has started operating last time).

[0056] As described above, the reaction force actuator 13 applies the first reaction torque T1 (the reaction torque T based on the neutral steering angle β_n) to the steering member 10 in the state where the driving source 51 is operating (see steps ST1 and ST8). Thereby, an appropriate reaction torque T based on the displacement of the steering member 10 with respect to the neutral steering angle β_n can be applied to the steering member 10 in the state where the driving source 51 is operating.

[0057] On the other hand, the reaction force actuator 13 applies the second reaction torque T2 (the reaction torque T based on the stopped time steering angle β_s) to the steering member 10 in the state where the driving source 51 is stopped (see step ST4). Thereby, an appropriate reaction torque T based on the displacement of the steering member 10 with respect to the stopped time steering angle β_s can be applied to the steering member 10 in the state where the driving source 51 is stopped. Therefore, it is possible to prevent the steering member 10 from being moved in a direction unintended by the driver and to prevent the reaction torque T in a direction unintended by the driver from being applied to the steering member 10 in the state where the driving source 51 is stopped. Therefore, it is possible to prevent the driver from feeling uncomfortable in a case where the driver touches the steering member 10 when getting on and out of the vehicle 2.

[0058] Further, the reaction force actuator 13 stops applying the second reaction torque T2 to the steering member 10 after applying the second reaction torque T2 to the steering member 10 for the prescribed period X in the state where the driving source 51 is

stopped (see step ST6). Thereby, the operation time of the reaction force actuator 13 can be reduced in the state where the driving source is stopped, so that power consumption of the vehicle steering system 1 can be suppressed. In other embodiments, the reaction force actuator 13 may always apply the second reaction torque T2 to the steering member 10 in the state where the driving source 51 is stopped.

[0059] As described above, the maximum value M2 of the absolute value of the reaction torque T in the second control map (see Figure 2B) is smaller than the maximum value M1 of the absolute value of the reaction torque T in the first control map (see Figure 2A). Therefore, the maximum value of the second reaction torque T2 (the reaction torque T in the state where the driving source 51 is stopped) is smaller than the maximum value of the first reaction torque T1 (the reaction torque T in the state where the driving source 51 is operating). Therefore, electric power necessary for the operation of the reaction force actuator 13 can be reduced in the state where the driving source 51 is stopped, so that the power consumption of the vehicle steering system 1 can be further suppressed. In other embodiments, the maximum value of the second reaction torque T2 may be equal to or larger than the maximum value of the first reaction torque T1.

[0060] Further, when the driving source 51 that has been stopped starts operating, the reaction force actuator 13 applies the first reaction torque T1, which is based on the neutral steering angle β_n in the last operation period of the driving source 51, to the steering member 10 (see step ST8). Accordingly, when the driving source 51 that has been stopped starts operating, the reaction torque T applied to the steering member 10 can be shifted from the second reaction torque T2 to the first reaction torque T1. Therefore, it is possible to prevent the driver from feeling uncomfortable when the driver performs the steering operation on the steering member 10 in the state where the driving source 51 is operating.

[0061] Further, the reaction force actuator 13 applies the second reaction torque T2 to the steering member 10 such that the steering member 10 is restored to the stopped time steering angle β_s in the state where the driving source 51 is stopped (see step ST4). Accordingly, the steering member 10 can be restored to the stopped time steering angle β_s even if the driver touches the steering member 10 (for example, the steering wheel 19) to displace the steering member 10 from the stopped time steering angle β_s in the state where the driving source is stopped. Therefore, it is possible to more effectively prevent the driver from feeling uncomfortable.

[0062] By the way, the driving source 51 may start operating during the restoration of the steering member 10 to the stopped time steering angle β_s in the state where the driving source 51 is stopped. In this case, the reaction force actuator 13 may apply the first reaction torque T1 to the steering member 10 after the restoration of the steering

member 10 to the stopped time steering angle β_s is completed. Accordingly, it is possible to apply the first reaction torque T1 to the steering member 10 after the steering member 10 is rotated to a position where the turning angle α matches the steering angle β . Thereby, it is possible to suppress a phase difference between the turning angle α and the steering angle β .

[0063] Further, the steering member 10 may accept the steering operation during the restoration of the steering member 10 to the stopped time steering angle β_s in the state where the driving source 51 is stopped. In this case, the reaction force actuator 13 may stop the restoration of the steering member 10 to the stopped time steering angle β_s and shift the reaction torque T applied to the steering member 10 from the second reaction torque T2 to the first reaction torque T1. Accordingly, it is possible to shorten a period to complete the shift of the reaction torque T, compared with a case where the reaction torque T is shifted after the steering member 10 is restored to the stopped time steering angle β_s . Preferably, the reaction force actuator 13 may gradually shift the reaction torque T applied to the steering member 10 from the second reaction torque T2 to the first reaction torque T1 in a case where the steering member 10 accepts the steering operation during the restoration of the steering member 10 to the stopped time steering angle β_s in the state where the driving source 51 is stopped. Thereby, it is possible to suppress the driver from feeling uncomfortable due to a sudden change in the reaction torque T.

[0064] In the present embodiment, the steering member 10 is rotatably provided. On the other hand, in other embodiments, the steering member 10 may be provided so as to be linearly movable in the fore and aft direction or the lateral direction. In this case, the reaction force that the reaction force actuator 13 applies to the steering member 10 may be a linear reaction force instead of the reaction torque T.

[0065] In the present embodiment, the turning mechanism 11 is always mechanically separated from the steering member 10. On the other hand, in other embodiments, a state where the turning mechanism 11 is mechanically separated from the steering member 10 and a state where the turning mechanism 11 is mechanically connected to the steering member 10 may be switched by a clutch.

[0066] Concrete embodiments of the present invention have been described in the foregoing, but the present invention should not be limited by the foregoing embodiments and various modifications and alterations are possible within the scope of the present invention.

List of the Numerals

- [0067] 1: vehicle steering system
2: vehicle
3. front wheels (an example of wheels)

10: steering member

11: turning mechanism

13: reaction force actuator

51: driving source

Claims

- [Claim 1] A vehicle steering system provided in a vehicle that travels by a driving force generated by a driving source, comprising;
a steering member configured to accept a steering operation; and
a reaction force actuator configured to apply a reaction force to the steering member in response to the steering operation, wherein
in a state where the driving source is stopped, the reaction force actuator is configured to apply the reaction force to the steering member based on a stopped time position that is a position of the steering member at a time when the driving source is stopped.
- [Claim 2] The vehicle steering system according to claim 1, wherein
in the state where the driving source is stopped, the reaction force actuator is configured to change the reaction force applied to the steering member based on displacement of the steering member with respect to the stopped time position.
- [Claim 3] The vehicle steering system according to claim 1 or 2, wherein
in the state where the driving source is stopped, the reaction force actuator is configured to stop applying the reaction force to the steering member after applying the reaction force to the steering member for a prescribed period.
- [Claim 4] The vehicle steering system according to any one of claims 1 to 3, wherein
a maximum value of the reaction force that the reaction force actuator applies to the steering member in the state where the driving source is stopped is smaller than a maximum value of the reaction force that the reaction force actuator applies to the steering member in a state where the driving source is operating.
- [Claim 5] The vehicle steering system according to any one of claims 1 to 4, wherein
when the driving source starts to operate, the reaction force actuator is configured to apply the reaction force to the steering member based on a prescribed neutral position of the steering member in a last operation period of the driving source.
- [Claim 6] The vehicle steering system according to any one of claims 1 to 5, wherein
in the state where the driving source is stopped, the reaction force actuator is configured to apply the reaction force to the steering

member such that the steering member is restored to the stopped time position.

[Claim 7]

The vehicle steering system according to claim 6, wherein in a state where the driving source is operating, the reaction force actuator is configured to apply the reaction force to the steering member based on a prescribed neutral position of the steering member, and

in a case where the driving source starts operating during restoration of the steering member to the stopped time position, the reaction force actuator is configured to apply the reaction force to the steering member based on the neutral position after the restoration of the steering member to the stopped time position is completed.

[Claim 8]

The vehicle steering system according to claim 7, wherein in a case where the steering member accepts the steering operation during the restoration of the steering member to the stopped time position, the reaction force actuator is configured to stop the restoration of the steering member to the stopped time position and to shift the reaction force applied to the steering member from the reaction force based on the stopped time position to the reaction force based on the neutral position.

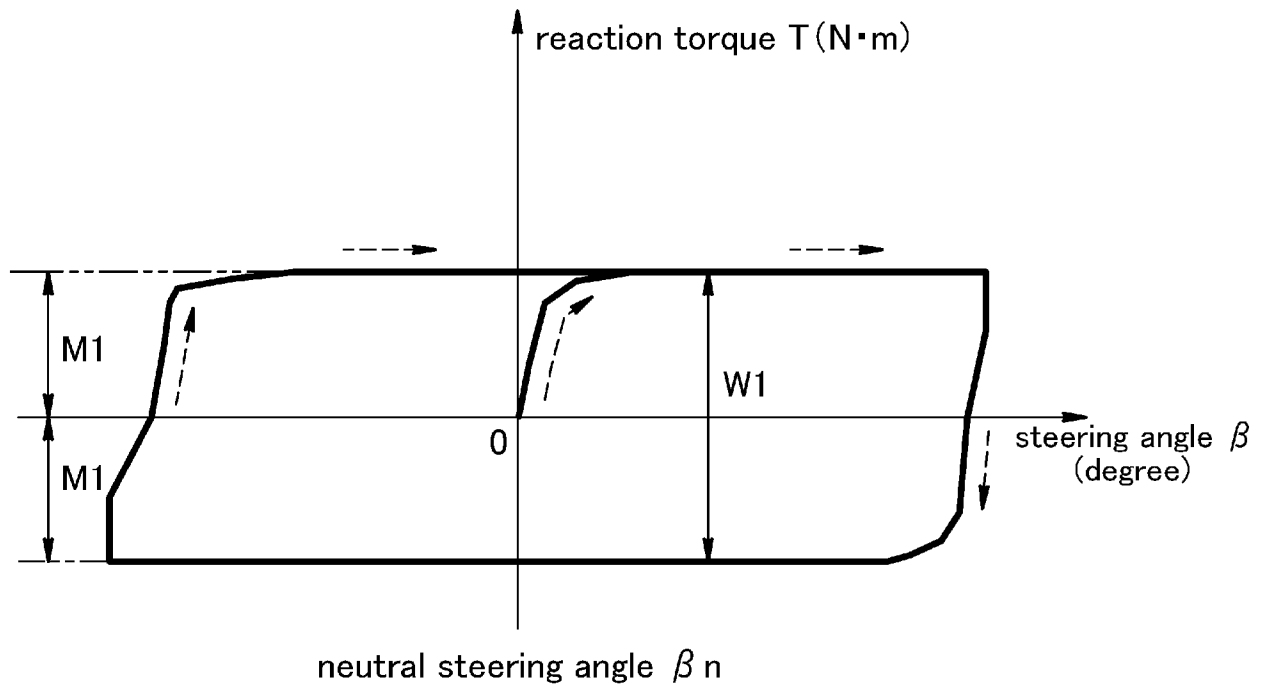
[Claim 9]

The vehicle steering system according to any one of claims 1 to 8, wherein the steering member is rotatably provided on a vehicle body, and the reaction force actuator is configured to apply reaction torque to the steering member.

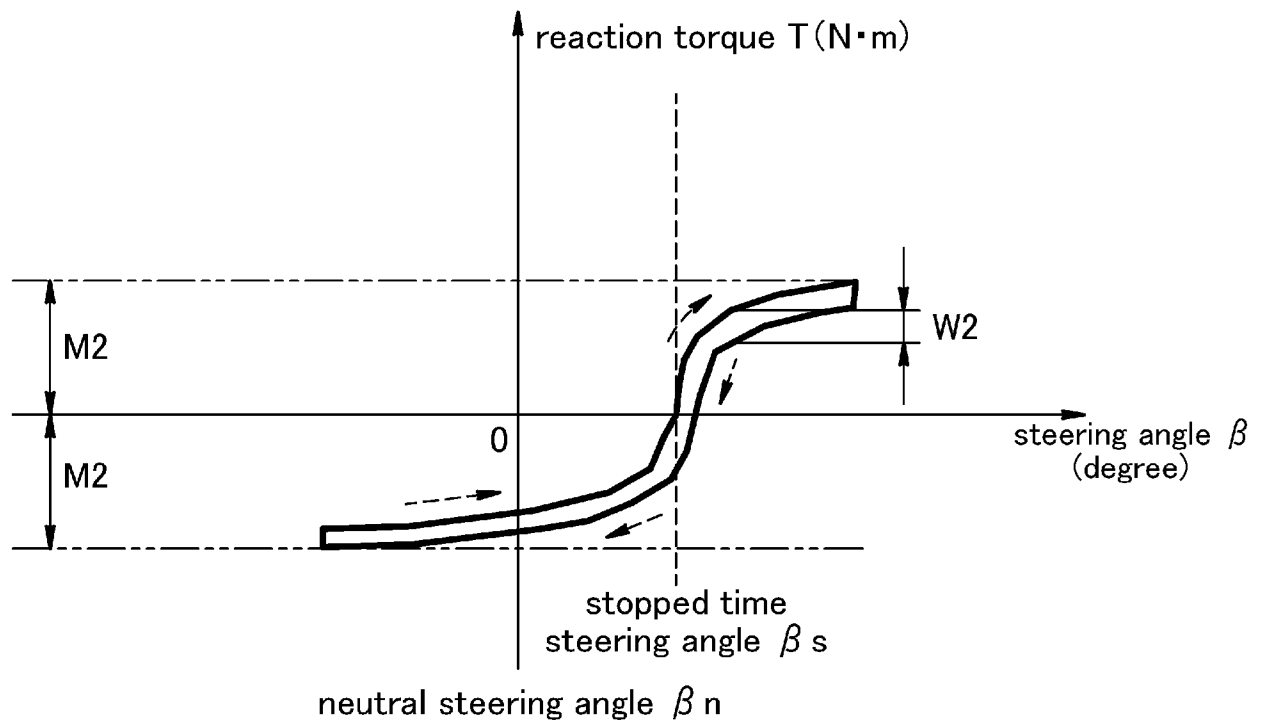
[Claim 10]

The vehicle steering system according to any one of claims 1 to 9, further comprising a turning mechanism mechanically separated from the steering member and configured to change a turning angle of wheels.

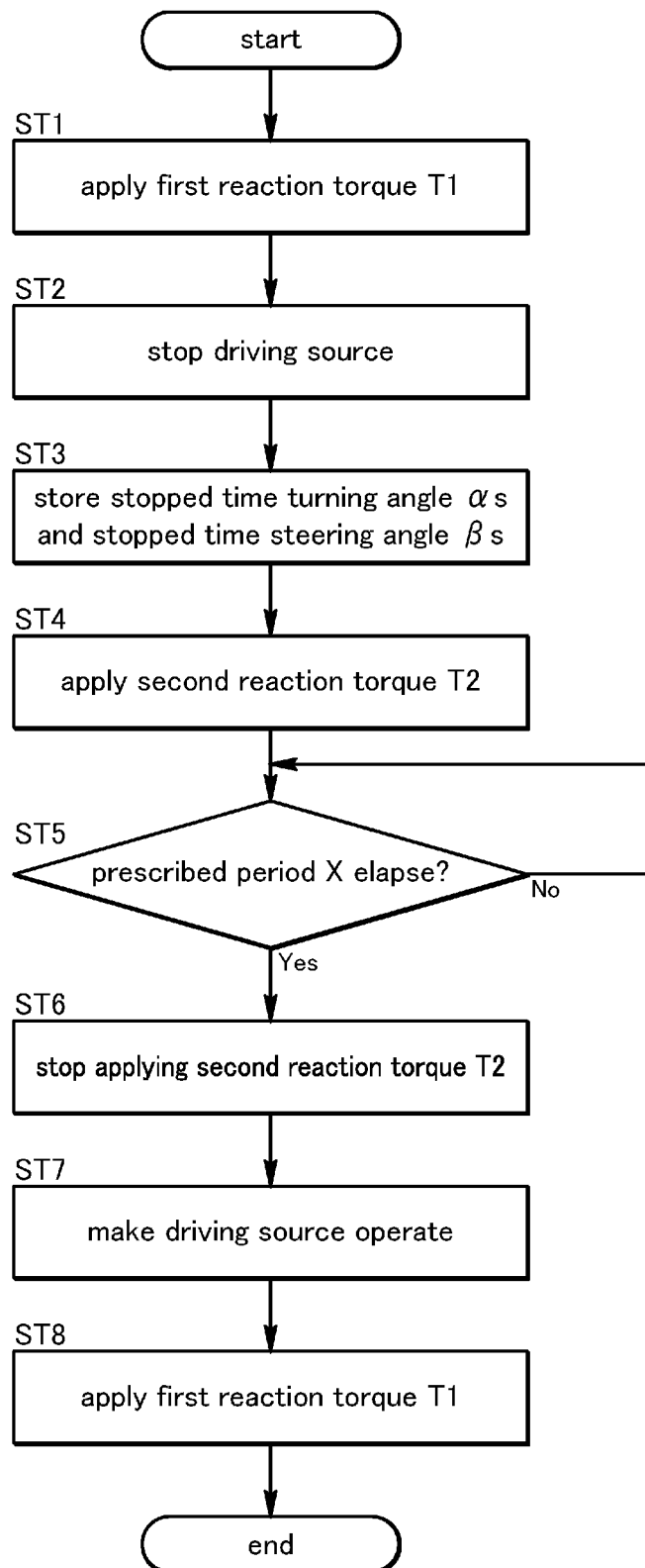
[Fig. 2A]



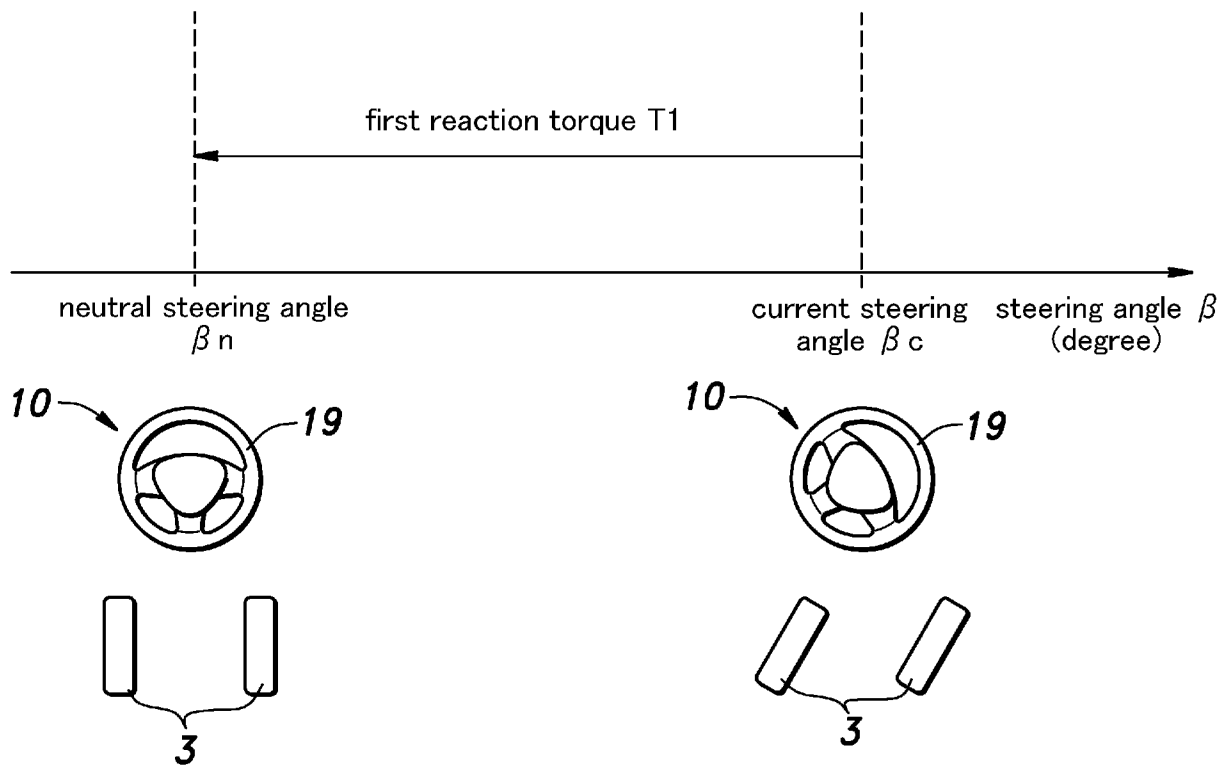
[Fig. 2B]



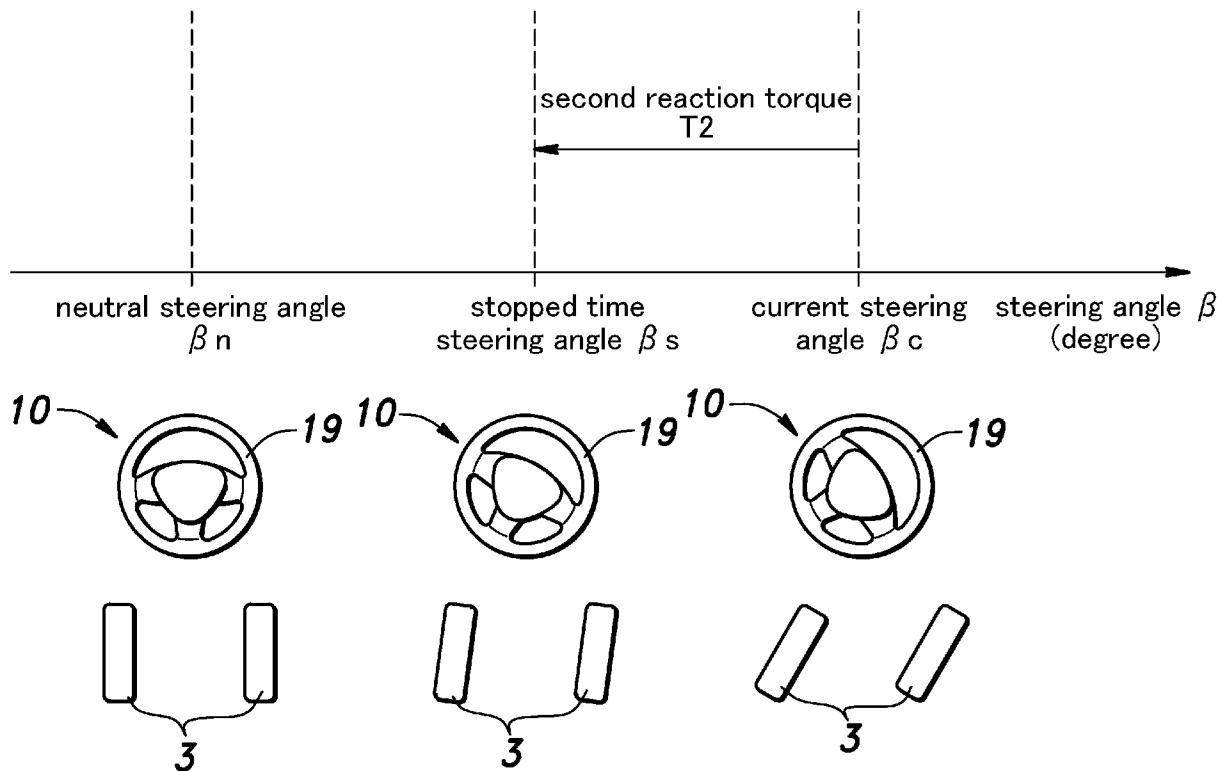
[Fig. 3]



[Fig. 4A]



[Fig. 4B]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2020/009971

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62D5/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B62D B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/347356 A1 (MATSUDA SATOSHI [JP] ET AL) 1 December 2016 (2016-12-01) paragraphs [0014] - [0018], [0021] - [0023], [0034], [0039] - [0048], [0095], [0096], [0098]; figures 1,2 -----	1-10
X	DE 10 2014 016017 A1 (AUDI AG [DE]) 4 May 2016 (2016-05-04) paragraphs [0002], [0009], [0022] - [0025]; figure 1 -----	1,2,5-7, 9,10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 November 2020

Date of mailing of the international search report

03/12/2020

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Kulozik, Ehrenfried

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2020/009971

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016347356 A1	01-12-2016	CN 106184349 A	07-12-2016
		EP 3098139 A1	30-11-2016
		US 2016347356 A1	01-12-2016

DE 102014016017 A1	04-05-2016	NONE	
