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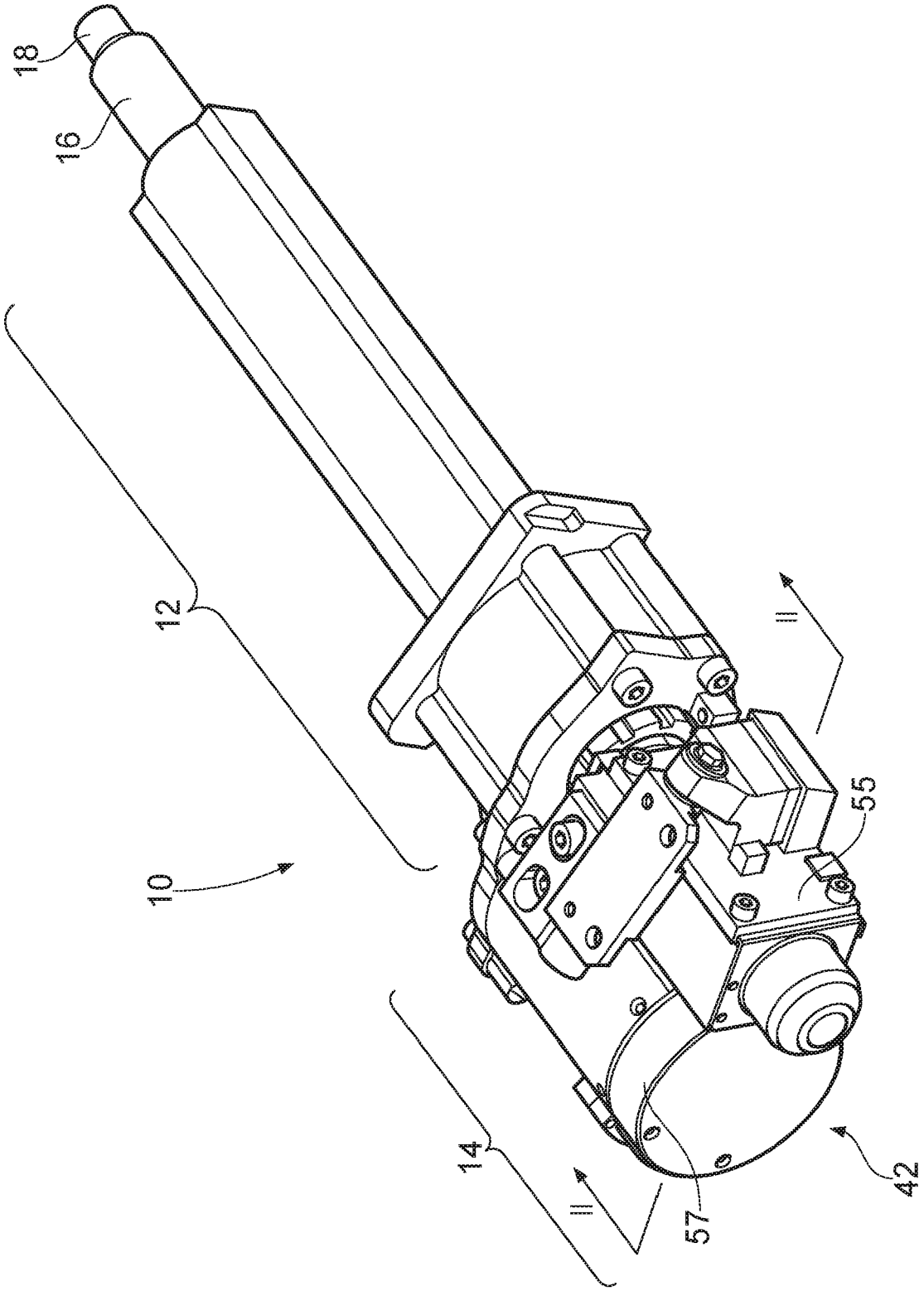

FIG. 1

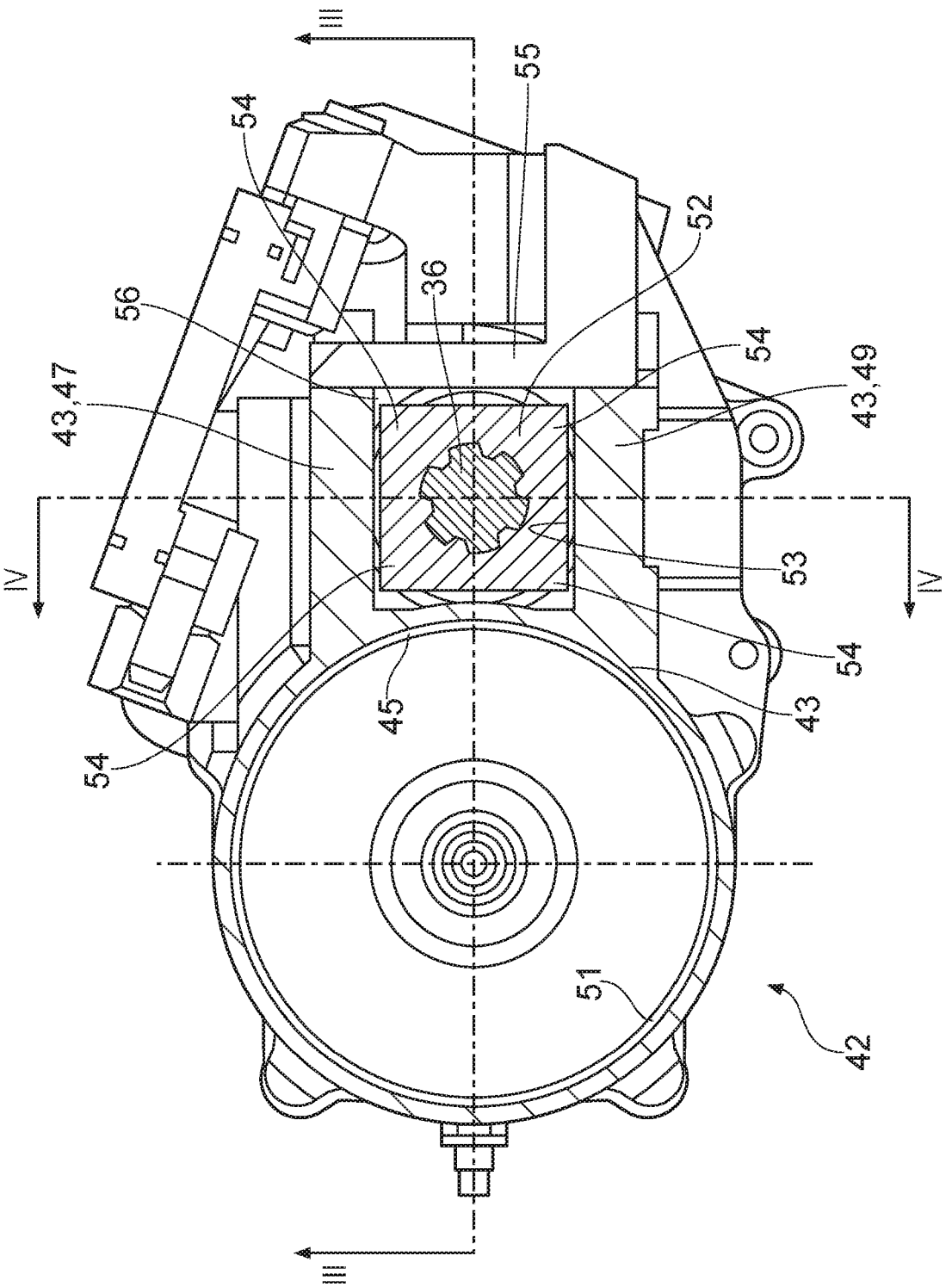

FIG. 2

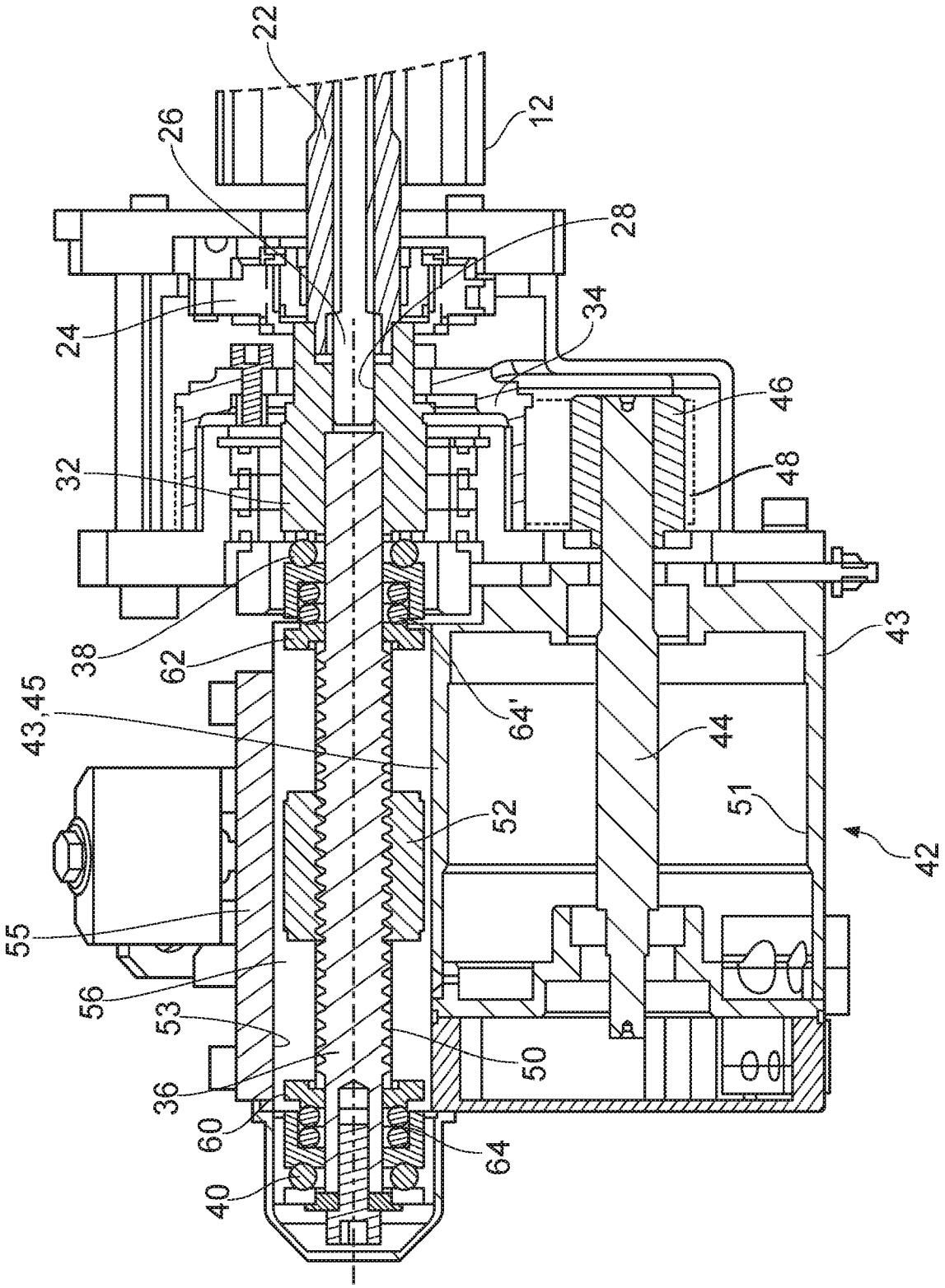
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FIG. 3

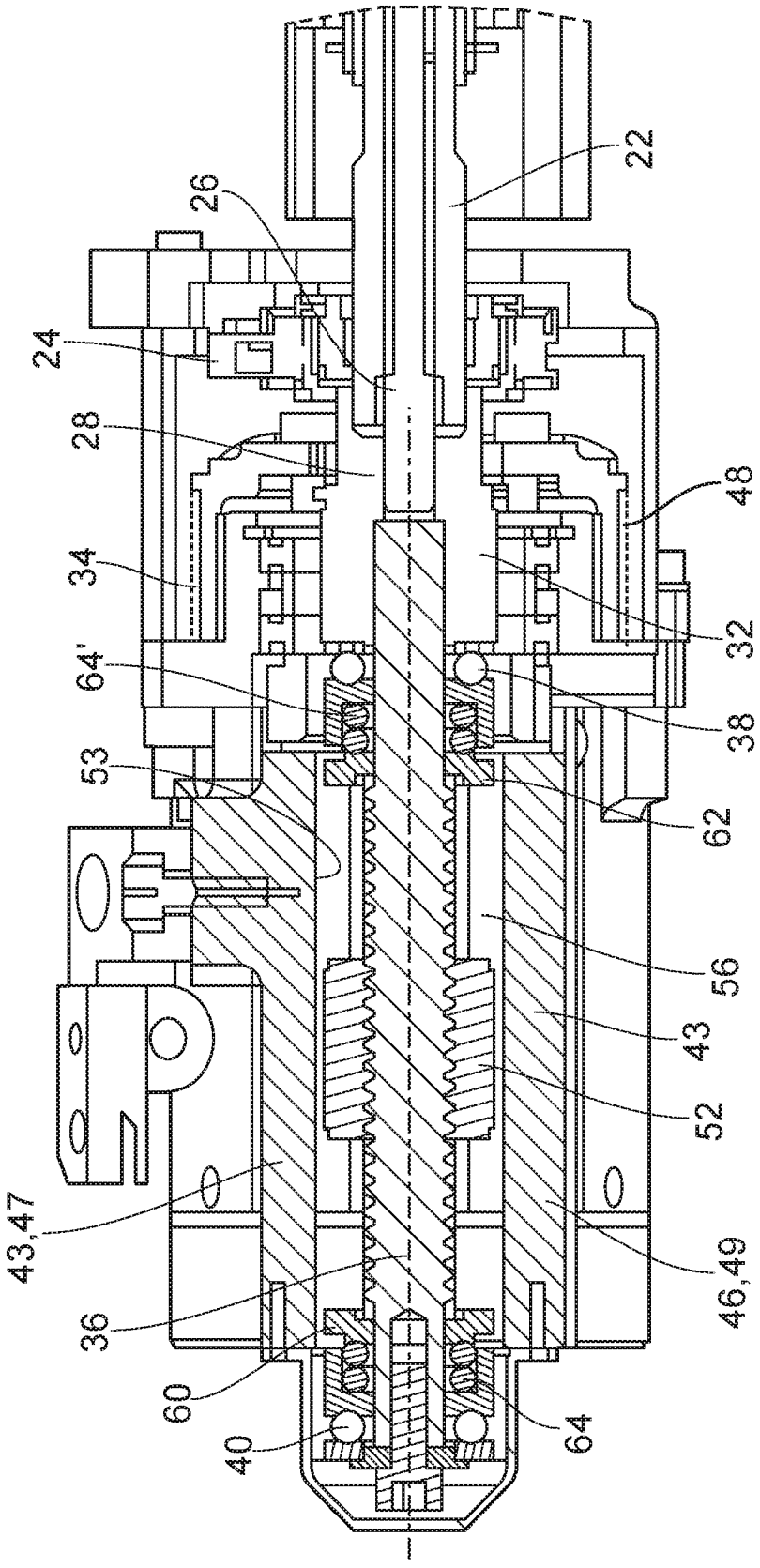

FIG. 4

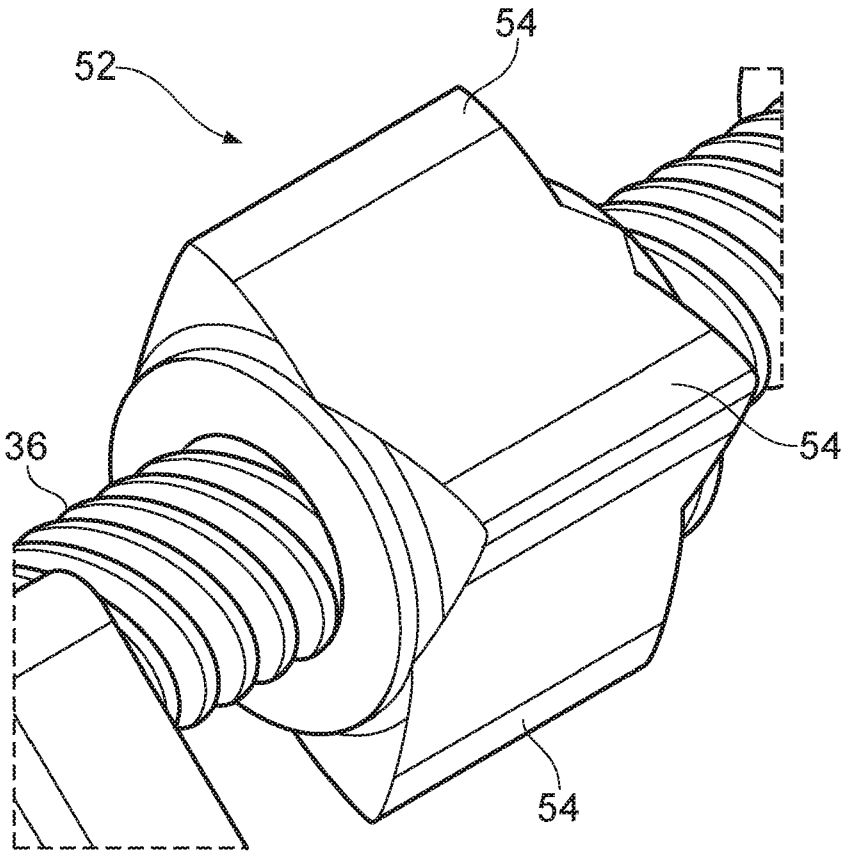

FIG. 5

A steering column assembly for a vehicle

The present invention relates to steering column assemblies and in particular, but not exclusively, to steering column assemblies for use with a steer-by-wire hand wheel actuator.

In steer-by-wire arrangements, a hand wheel (steering wheel) is connected to one end of a shaft whose angular displacement is measured to generate a signal which is used to control the orientation of the steered wheels of the vehicle. Such arrangements are commonly also provided with an electric motor connected to the shaft to apply a torque in the opposite direction to the torque applied at the steering wheel in order to provide a sensation of road feel to the driver.

In steer-by-wire arrangements, it is important to limit the rotation of the steering wheel and the shaft to which it is connected to ensure that the maximum rotation of the steering wheel in both directions corresponds to the maximum pivoting of the steered wheels in both directions. If the rotation of the steering wheel is not limited, it would still be possible to rotate the steering wheel when the steered wheels are pivoted to their maximum pivoted angle, such that the rotational position of the steering wheel would no longer correspond to the position of the steered wheels.

One method of limiting the rotation of the steering wheel (and, in particular, the shaft to which the steering wheel is connected) is to provide a screw-threaded rod which rotates with the steering wheel. A nut is threadedly mounted on the screw-threaded rod and is prevented from rotating, whereby rotation of the steering wheel, and therefore the screw-threaded rod which rotates with it, results in longitudinal displacement of the nut along the screw-threaded rod. By

providing end stops, the longitudinal displacement of the nut along the screw-threaded rod - and therefore the maximum rotation of the steering wheel in both directions - is limited.

However, it is important to ensure that the driver's steering feel is not harmed by any friction or inertia within the steering drive train. In particular, it is important to ensure that the longitudinal displacement of the nut along the screw-threaded rod is not impeded as this would be felt by the driver and in an extreme situation the nut could seize or lock in position, which could prevent the driver from steering the vehicle.

It is an aim of the present invention to overcome or reduce the problems of such known steering column assemblies.

In accordance with a first aspect of the present invention, a steering column assembly for a vehicle, comprises:

a housing;

a shaft rotatably mounted with respect to the housing and being configured for attachment of a steering wheel at one end;

an elongate rod configured to rotate with the rotatably mounted shaft and comprising a screw-threaded portion;

a nut member threadedly mounted on the screw-threaded portion of the elongate rod;

an elongate guide for the nut member which restricts rotation of the nut member with respect to the housing, wherein the elongate guide comprises a channel which receives the nut member and whereby rotation of the elongate rod causes axial displacement of the nut member along the rod; and

end stops positioned to engage with the nut member to define the maximum axial displacement of the nut member along the elongate rod in both directions;

wherein a clearance is provided between the elongate guide and the nut member.

By providing a clearance between the elongate guide and the nut member, misalignment of the screw-threaded rod is tolerated. In particular, it ensures that any runout in the screw-threaded rod will not cause the nut member to foul on the elongate guide, as any fouling would be felt by a driver and could cause the nut member to seize or otherwise lock in position.

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Preferably, the clearance between the channel and the nut member is achieved by making the channel oversized with respect to the nut member.

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This allows the nut member to rotate slightly with the screw-threaded rod until the nut member engages with the guide channel, after which further rotation of the screw-threaded rod results in longitudinal displacement of the nut member along the guide channel.

Preferably, the nut member is non-circular in cross section.

The channel is preferably complementarily-shaped with the nut member, with a clearance between the channel and the nut member.

In one embodiment, the nut member comprises a plurality of faces.

One or more of the faces of the nut member may be recessed.

By providing a recess on one or more of the faces of the nut member, several lobes are effectively formed on the nut member, which are engageable with the guide channel.

Preferably, the elongate guide is located in the housing.

Preferably, the elongate rod and the rotatably mounted shaft are coaxial.

The steering column assembly preferably further comprises a sensor configured to generate an electrical signal in response to rotation of the rotatably mounted shaft.

The steering column assembly preferably further comprises a motor configured to apply a torque to the rotatably mounted shaft in the opposite direction to an externally-applied torque.

The nut member is preferably formed from a non-metallic material, for example a plastics material.

The nut member may be formed from a material which is less dense than the screw-threaded rod.

By having a nut member of low mass, the inertia of the nut transitioning from one direction to the other is low and will not be felt by the driver as any form of disturbance.

In accordance with a second aspect of the present invention, a steering column assembly for a vehicle, comprises:

a housing;

a shaft rotatably mounted with respect to the housing and being configured for attachment of a steering wheel at one end;

a sensor configured to generate an electrical signal in response to rotation of the rotatably mounted shaft;

a motor configured to apply a torque to the rotatably mounted shaft in the opposite direction to an externally-applied torque;

an elongate rod arranged coaxially with, and configured to rotate with, the rotatably mounted shaft and comprising an externally screw-threaded portion;

a nut member threadedly mounted on the screw-threaded portion of the elongate rod, the nut member being non-circular in cross section;

an elongate guide channel in which the nut member is located, which restricts rotation of the nut member with respect to the housing, whereby rotation of the elongate rod causes axial displacement of the nut member along the rod, wherein the guide channel is coaxial with the elongate rod and is complementarily-shaped with the nut member with a clearance between the channel and the nut member; and

end stops positioned to engage with the nut member to define the maximum axial displacement of the nut member along the elongate rod in both directions.

Preferably, the nut member comprises a plurality of faces.

Preferably, one or more of the faces of the nut member are recessed.

The nut member is preferably formed from a non-metallic material, for example a plastics material.

The nut member may be formed from a material which is less dense than the screw-threaded rod.

The present invention also includes a vehicle comprising a steering column assembly in accordance with the present invention.

By way of example only, a specific embodiment of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of an embodiment of steer-by-wire hand wheel actuator in accordance with the present invention;

Figure 2 is a transverse cross section of the actuator of Figure 1, looking in the direction of arrows II - II;

Figure 3 is a longitudinal cross-section of the actuator of Figure 1, looking the direction of arrows III – III of Figure 2;

Figure 4 is a longitudinal cross-section of the actuator of Figure 1, looking the direction of arrows IV – IV of Figure 2; and

Figure 5 is a perspective view to an enlarged scale of a nut and leadscrew which form part of the actuator of Figure 1.

A steer-by-wire hand wheel actuator 10 comprises an elongate metal steering column housing 12 and an actuator assembly 14 secured to one end of the steering column housing 12. A steering shaft 16 passes coaxially through the elongate metal housing 12 and in use a steering wheel (not shown) is connected to the outer end 18 of the steering shaft 16. The steering shaft 16 is rotatably supported on bearings (not shown) within the housing 12.

The inner end 22 of the steering shaft 16 is connected to a conventional torque/angle sensor 24 which produces electrical signals as a function of the rotational position of the steering wheel and steering shaft 16. The electrical signals are used in a known manner to control the angular position of the steered wheels of a vehicle in a steer-by-wire control arrangement.

The inner end 22 of the steering shaft 16 is also connected by means of a quill shaft 26 to an internally splined aperture 28 of a hub 32 to which a steering shaft pulley 34 is connected.

The hub 32 is rotatably mounted within the housing 14. The opposite end of the splined aperture 28 is enlarged and receives one end of a leadscrew 36 which is aligned coaxially with the steering shaft 16 and which is rotatably mounted by means of bearings 38, 40 within the actuator housing 43 of the actuator assembly 14 at its opposite ends.

An electric motor 42 is also mounted within the actuator housing 43 and is configured to drive output shaft 44 arranged parallel to the leadscrew 36 and to one projecting end of which an output pinion 46 is connected. A transmission belt 48 is fed around the output pinion 46 and around the steering shaft pulley 32, and the motor 42 is actuated to apply a torque, in order to provide feedback to the steering shaft 16 so as to produce a sensation of road feel to the

driver. The applied torque is felt by the driver as a haptic feedback or to control the angle of the steering wheel.

The leadscrew 36 is made from metal, for example steel, and is threaded for most of its length as shown at 50. Like the electric motor 42, a plastic leadscrew nut 52 is disposed within the actuator housing 43 (see FIGS. 2 and 4). The plastic leadscrew nut 52 is readily received on the threaded portion 50 of the leadscrew 36. Accordingly, as shown in FIGS. 2 and 3, the threaded portion 50 of the leadscrew 36 is similarly disposed within the actuator housing 43. The actuator housing 43 defines a chamber 51 for housing the electric motor 42 and a cavity 53 (adjacent to the chamber 51). The cavity 53 is configured to house the threaded portion 50 of the leadscrew 36 and the leadscrew nut 52. A dividing wall portion 45 of the actuator housing 43 is disposed between the chamber 51 and the cavity 53. As shown in FIG. 2, the cavity 53, the dividing wall portion 45, and the chamber 51 may be integral to each other in order to form the actuator housing 43. With reference to FIG. 2, the cavity 53 may include first and second wall portions 47, 49 which extend from the dividing wall portion 45. First cover 55 may be affixed to first and second wall portions 47, 49 of the actuator housing 43 during the assembly process in order to enclose the plastic leadscrew 52 within the actuator housing 43. Similarly, a second cover 57 may be separately provided as shown in FIG. 1 to easily enclose the electric motor 42 within the actuator housing 43 during the assembly process. The aforementioned arrangement of the actuator assembly 14 (electric motor 42, leadscrew 36 and leadscrew nut 52 relative to the actuator housing 43) requires minimal vehicle packaging space relative to traditional arrangements.

As best seen Figure 2, nut 52 is generally square in cross section but its four faces are recessed slightly so that the four corners of the nut form lobes 54. As shown in Figures 2 to 4, the nut 52 is constrained to move within the cavity 53 which is provided in the form of an elongate channel 56 in FIGS. 2 and 3. As shown in FIGS. 2 and 3, the elongate channel 56

is defined by dividing wall portion 45 and first and second walls portions 47, 49 of the actuator housing 43. As shown, the elongate channel 56 may be generally square-shaped to at least partially constrain nut 52. However, the nut 52 is not a tight fit within the channel 56. Instead, the channel 56 is oversized with respect to the nut 52 (or the nut 52 is undersized with respect to the channel 56) so that there is a clearance between the nut 52 and the channel 56, such that the nut 52 is a loose fit in the channel 56.

As the leadscrew 36 is rotated by means of the steering shaft 16, the nut 56 can rotate slightly by a few degrees before it engages the walls of the channel 56. When the nut 52 is engaged with the walls of the channel 56, it is prevented from rotating further, and further rotation of the leadscrew 36 causes the nut 50 to be displaced longitudinally along the leadscrew.

The maximum displacement of the nut 52 along the leadscrew 56 is determined by first and second end stops 60, 62 located within the housing 14. A respective pair of rubber O-rings 64, 64' is positioned behind each end stop 60, 62 in order to provide a damping effect, in order to cushion the contact between the nut 52 and the end stops 60, 62. Furthermore the end stops 60, 62 include thrust bearings 38, 40 which prevent the nut 52 from locking up when reaching the end of travel along leadscrew 56.

By providing a clearance between the channel 56 and the nut 52, any misalignment of the screw-threaded rod 36 is tolerated. In particular, it ensures that any runout in the screw-threaded rod 36 will not cause the nut 52 to foul on the walls of the channel 56, as any fouling would be felt by a driver and could cause the nut 52 to seize or otherwise lock in position.

In addition, by forming the nut 52 of lightweight material, for example plastics material, the driver's steering feel is not harmed by friction or inertia within the steering drive train. In

addition, having a nut 52 of low mass assists in situations of steering reversal, as inertia when transitioning from one direction to the other is low and will not be felt by the driver as a disturbance. However, the nut 52 may be formed of other lightweight material or materials. For example, it may be formed of lightweight material or materials which are of a lower density than that of the screw-threaded rod 36 on which it is threadedly mounted.

The invention is not restricted to the details of foregoing embodiment.

CLAIMS

1. A steering column assembly for a vehicle, comprising:

a housing;

a shaft rotatably mounted with respect to the housing and being configured for attachment of a steering wheel at one end;

an elongate rod configured to rotate with the rotatably mounted shaft and comprising a screw-threaded portion;

a nut member threadedly mounted on the screw-threaded portion of the elongate rod;

an elongate guide for the nut member which restricts rotation of the nut member with respect to the housing, wherein the elongate guide comprises a channel which receives the nut member and whereby rotation of the elongate rod causes axial displacement of the nut member along the rod; and

end stops positioned to engage with the nut member to define the maximum axial displacement of the nut member along the elongate rod in both directions;

wherein a clearance is provided between the elongate guide and the nut member.

2. A steering column assembly as claimed in claim 1, wherein the channel is oversized with respect to the nut member.

3. A steering column assembly as claimed in claim 1 or claim 2, wherein the nut member is non-circular in cross section.

4. A steering column assembly as claimed in claim 3, wherein the channel is complementarily-shaped with the nut member with a clearance between the channel and the nut member.

5. A steering column assembly as claimed in claim 3 or claim 4, wherein the nut member comprises a plurality of faces.

6. A steering column assembly as claimed in claim 5, wherein one or more of the faces of the nut member are recessed.

7. A steering column assembly as claimed in any of the preceding claims, wherein the elongate guide is located in the housing.

8. A steering column assembly as claimed in any of the preceding claims, wherein the nut member is formed from a non-metallic material.

9. A steering column assembly as claimed in any of the preceding claims, wherein the member is formed from a material which is less dense than the screw-threaded rod.

10. A steering column assembly as claimed in any of the preceding claims, wherein the elongate rod and the rotatably mounted shaft are coaxial.

11. A steering column assembly as claimed in any of the preceding claims, further comprising a sensor configured to generate an electrical signal in response to rotation of the rotatably mounted shaft.

12. A steering column assembly as claimed in claim 11, further comprising a motor configured to apply a torque to the rotatably mounted shaft in order to provide a haptic feedback to the driver, or to control the angle of the steering wheel.

13. A steering column assembly for a vehicle, comprising:

a housing;

a shaft rotatably mounted with respect to the housing and being configured for attachment of a steering wheel at one end;

a sensor configured to generate an electrical signal in response to rotation of the rotatably mounted shaft;

a motor configured to apply a torque to the rotatably mounted shaft in order to provide a haptic feedback to the driver, or to control the angle of the steering wheel;

an elongate rod arranged coaxially with, and configured to rotate with, the rotatably mounted shaft and comprising an externally screw-threaded portion;

a nut member threadedly mounted on the screw-threaded portion of the elongate rod, the nut member being non-circular in cross section;

an actuator housing defining a chamber to house the motor and a cavity in the form of an elongate guide channel in which the nut member is located, which restricts rotation of the nut member with respect to the housing, whereby rotation of the elongate rod causes axial displacement of the nut member along the rod, wherein the guide channel is coaxial with the elongate rod and is complementarily-shaped with the nut member with a clearance between the channel and the nut member; and

end stops positioned to engage with the nut member to define the maximum axial displacement of the nut member along the elongate rod in both directions.

14. A steering column assembly as claimed in claim 13, wherein the nut member comprises a plurality of faces.

15. A steering column assembly as claimed in claim 14, wherein one or more of the faces of the nut member are recessed.

16. A steering column assembly as claimed in any of claims 13 to 15, wherein the nut member is formed from a non-metallic material.

17. A steering column assembly as claimed in any claims 13 to 16, wherein the member is formed from a material which is less dense than the screw-threaded rod.

18. A vehicle comprising a steering column assembly as claimed in any of the preceding claims.