US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12391303
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	LePage; Gabriel

Interface for EPS servo unit

Abstract

An electric power steering system includes an electric motor, a steering rack drivable along a steering rack axis with power from the electric motor, and a mechanical coupling between the electric motor and the steering rack for transmitting power from the electric motor to the steering rack. The mechanical coupling is enclosed within a housing. A compression fitting interface couples the electric motor and the housing.

Inventors:	**LePage; Gabriel (Royal Oak, MI)**
Applicant:	**Robert Bosch GmbH** (Stuttgart, DE)
Family ID:	**1000008763586**
Assignee:	**Robert Bosch GmbH (Stuttgart, DE)**
Appl. No.:	**17/696770**
Filed:	**March 16, 2022**

Prior Publication Data

Document Identifier	**Publication Date**
US 20230294756 A1	Sep. 21, 2023

Publication Classification

Int. Cl.: **B62D5/04** (20060101); **B62D3/12** (20060101)

U.S. Cl.:

CPC **B62D5/0424** (20130101); **B62D3/12** (20130101);

Field of Classification Search

CPC: B62D (5/0421); B62D (5/0424); B62D (3/12)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
5213173	12/1992	Konishi et al.	N/A	N/A
5836419	12/1997	Shimizu et al.	N/A	N/A
6805017	12/2003	Chikaraishi	180/443	B62D 5/0409
7413051	12/2007	Okada	180/444	B62D 5/0424
7591204	12/2008	Ueno et al.	N/A	N/A
7822520	12/2009	Takeuchi	701/41	B62D 5/0463
8360910	12/2012	Leutner	N/A	N/A
8950543	12/2014	Heo et al.	N/A	N/A
9802641	12/2016	Tomikawa	N/A	N/A
9933050	12/2017	Yamamoto	N/A	N/A
2005/0247514	12/2004	Heitzer	180/444	F16H 7/14

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
1266817	12/2001	EP	B62D 5/0424

OTHER PUBLICATIONS

Bosch, “Electric Power Steering Belt Drive Servo Unit”, Product Information, 2021, 8 pages. cited by applicant
Bosch, “Electric Power Steering (EPS) Servolectric”, Product Information, 2019, 2 pages. cited by applicant
Bosch, “Servolectric”, 2015, Product Information, 18 pages. cited by applicant

Primary Examiner: Knutson; Jacob D

Attorney, Agent or Firm: Michael Best & Friedrich LLP

Background/Summary

BACKGROUND

(1) The present invention relates to electric power steering systems (EPS). EPS has begun to dominate many sectors of vehicles as a more efficient replacement for conventional hydraulic-assisted power steering. In some forms, an electric motor is placed alongside the steering rack and controlled to provide steering assistance, or automated steering response to turn the vehicle's front wheels. The electric motor can have an output shaft provided with a toothed disc thereon for driving the steering rack through a flexible belt. Such products are known in the art, including those from Robert Bosch Automotive Steering and designated in the market as Servolectric®. One such example is shown in FIG. **1** where the electric motor **20** is arranged with an axis A parallel to an

axis B of the steering rack **24**. The electric motor **20** output shaft supports a toothed disc **28** meshed with a flexible belt **32** to drive a secondary toothed disc **36** for rotating a ball recirculating nut **40** to assist in driving movement of the steering rack **24** along the axis B. This type of mechanical coupling between the electric motor **20** and the steering rack **24** is used in what is referred to as an “axial parallel actuation” EPS construction. The motor **20** can be provided with an integrated electronic control unit **44** to form a so-called steering control unit (SCU). Between the SCU and the gearbox cover **48** that encloses the ball recirculating nut **40** and a portion of the steering rack **24**, an intermediate housing **52** is provided. The intermediate housing **52**, which is partially cutaway in FIG. **1** encloses the flexible belt **32** and the toothed discs **28**, **36**. The SCU is mated with the intermediate housing **52** by a plurality of threaded fasteners **56** that extend parallel to the axis A of the electric motor **20**. Tension in the flexible belt **32** is lost if the SCU is removed, since the toothed disc **28** is supported against the belt tension by the output shaft of the electric motor **20**.
(2) FIGS. **2** and **3** illustrate another type of EPS system, which is similar in many respects to that of FIG. **1**. Similar parts are labeled with consistent reference numerals. Although the motor **20** is oriented with its axis A parallel to the steering rack axis B like in FIG. **1**, the EPS system of FIGS. **2** and **3** actuates the steering rack **24** in a different way. Rather than a flexible belt spanning a pair of toothed discs, FIG. **3** illustrates a worm **64** extending from the output shaft **26** of the motor **20**, with the worm **64** configured to drive a helical gear **68**, which in turn is configured to drive rotation of a drive pinion **70** meshed with the teeth of the steering rack **24**. This type of mechanical coupling between the electric motor **20** and the steering rack **24** is used in what is referred to as a “dual pinion” EPS construction, as the drive pinion **70** provides a secondary pinion on the steering rack **24** spaced a distance from the primary pinion from the steering shaft.
SUMMARY
(3) In one aspect, the invention provides an electric power steering system including an electric motor, a steering rack drivable along a steering rack axis with power from the electric motor, and a mechanical coupling between the electric motor and the steering rack for transmitting power from the electric motor to the steering rack. The mechanical coupling is enclosed within a housing. A compression fitting interface couples the electric motor and the housing.
(4) In another aspect, the invention provides an electric power steering system including an electric motor having an output shaft, and a steering rack drivable along a steering rack axis with power from the electric motor. A belt is coupled between the electric motor and the steering rack for transmitting power of the electric motor to the steering rack, and the belt is enclosed within a belt housing and stretched to an operating belt tension by a first tooth disc and a second tooth disc. A boltless mounting interface secures the electric motor and the belt housing. The output shaft is axially releasable from the first toothed disc, the first toothed disc being supported in the belt housing to maintain the operating belt tension regardless of whether the electric motor is coupled to the housing.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a partial cutaway of an electric power steering system according to the prior art.
(2) FIG. **2** illustrates another electric power steering system according to the prior art.
(3) FIG. **3** is a partial cutaway of the electric power steering system of FIG. **2**.
(4) FIG. **4** is a partial cutaway of an electric power steering system according to one embodiment of the present disclosure in which power is conveyed to the steering rack via a pinion.
(5) FIG. **5** is a partially exploded assembly view of the electric power steering system of FIG. **4**.
(6) FIG. **6** is an end view of portions of the electric power steering system of FIGS. **4** and **5**, including an electric motor, a compression seal, and a compression screw plug.

(7) FIG. **7** is a front view of an alternate electric motor having an axial end interface different from that shown in FIGS. **4** and **5**.
(8) FIG. **8** is a detail view of a first exemplary ribbed compression seal.
(9) FIG. **9** is a detail view of a second exemplary ribbed compression seal.
(10) FIG. **10** is a detail view of an exemplary honeycomb compression seal surface.
(11) FIG. **11** is a partially exploded assembly view of an electric power steering system according to another embodiment of the present disclosure in which power is conveyed to the steering rack via a belt.

DETAILED DESCRIPTION

(12) Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

(13) FIGS. **4-7** illustrate an electric power steering (EPS) system **100** according to an embodiment of the present disclosure. The EPS system **100** can share some basic structure with the conventional EPS system shown in FIGS. **2** and **3** and briefly described above. For brevity, the figures and description are focused on aspects of the EPS system **100** which differ from the prior art, with the understanding that the components shown in FIGS. **4-7** can be used as replacements for components of the preceding figures and description. For example, FIGS. **4-7** do not illustrate a steering rack since it will be understood that the EPS system **100** can operate with a steering rack **24** as shown in FIGS. **1-3** and described above. For convenience, reference numbers used in FIGS. **4-7** are kept the same or incremented from “xx” to “lxx” compared to the preceding figures and description, as appropriate. The EPS system **100** includes an electric motor **120** placed alongside the steering rack **24** and controlled to provide steering assistance, or automated steering response to turn the vehicle's front wheels. The electric motor **120** has an output shaft **126** rotatable about an axis A. The axis A of the electric motor **120** is parallel to the axis B along which the steering rack **24** reciprocates. Reference is made directly to FIG. **2**, where the electric motor **120** can be provided in the position of the electric motor **20**. The EPS system **100** can be a so-called “dual pinion” system in which a worm **64** extends from the output shaft **126** of the motor **120**, with the worm **64** configured to drive the helical gear **68**, which in turn is configured to drive rotation of the drive pinion **70** meshed with the teeth of the steering rack **24**. Other mechanical couplings are optional, one of which is described further below with reference to FIG. **11**.

(14) The mechanical coupling for the dual pinion EPS system **100** is enclosed within a housing **152**. The housing **152** is similar to the housing **52** of FIGS. **2** and **3** in that it is an intermediate housing situated between the electric motor **120** and the gearbox cover **48** which receives the steering rack **24**. Within the housing **152**, a pair of bearings **172** support the worm **64** at opposite axial ends thereof. Mechanical coupling between the motor output shaft **126** and the worm **64** is provided by a collar **176**, which can be for example a hollow ring with internal splines for engaging complementary splines formed on the adjacent end portions of the motor output shaft **126** and the worm **64**. The adjacent splined end portions of the motor output shaft **126** and the worm **64** are both received into the collar **176** such that the collar **176** couples the motor output shaft **126** and the worm **64** for co-rotation when the motor **120** is operated.

(15) The electric motor **120** can be provided with an integrated electronic control unit **144** to form a so-called steering control unit (SCU) or servo unit. The electronic control unit **144** can be supported directly by the electric motor **120**, rather than remotely mounted at another position within the vehicle. For example, the electronic control unit **144** can be positioned at an axial end of the electric motor **120** which is opposite the end where the output shaft **126** extends into the housing **152**. In other constructions, the electronic control unit **144** may be supported at different

positions on the exterior of the electric motor **120**. The electronic control unit **144** contains at least one processor configured to calculate a control signal for driving the electric motor **120** to provide steering assistance when the vehicle steering wheel and steering shaft are rotated by input from a driver within the vehicle. In some constructions, the processor of the electronic control unit **144** is configured to calculate a control signal for driving the electric motor **120** to provide autonomous steering control, without input from driver within the vehicle. Steering assist and autonomous steering can be provided in different switchable modes of the vehicle, or the vehicle may be configured with only one or the other. One or more electrical connectors **146** are provided on the electronic control unit **144** and used to mate with electrical connectors of various electrical cables or wires, e.g., power to the motor **120**, signal output from a steering torque sensor, feedback to a main vehicle ECU, etc. The electric motor **120** is positioned with respect to the steering rack **24** so that the electrical connector(s) **146** are accessible for connection and disconnection, at the time of original vehicle assembly and/or field service.

(16) Especially in vehicles designated for extended lifetime service (e.g., commercial transport, delivery, etc.), there may be an eventual need for servicing the EPS system **100**, including removal/replacement of the electric motor **120**, (e.g., along with the integrated electronic control unit **144**). There is also the need to secure the electric motor **120** and the housing **152** by way of a solid and sealed connection therebetween. Conventional EPS systems rely on a plurality of bolts around a perimeter of the electric motor where it mates axially to a flange of the housing, and a seal may be compressed when the bolts are tightened. To the contrary, the EPS system **100** of the present disclosure is designed to include a boltless mounting interface between the electric motor **120** and the housing **152**. In particular, a compression fitting interface **180** is provided to couple the electric motor **120** and the housing **152**. In some constructions, the housing **152** and the electric motor **120** are axially coupled exclusively by the compression fitting interface **180**. As such, an axial end of the electric motor **120** is joined with a complementary portion of the housing **152**, without an axially interposed seal. Rather, sealing is accomplished between the outer periphery of the motor **120** and a receiving portion (or “flange”) **184** of the housing **152** that lies radially outside the motor **120**.

(17) The flange **184** of the housing **152** makes up one portion of the compression fitting interface **180**, the parts of which can be observed in greater detail in the exploded assembly view of FIG. **5**. The flange **184** can be integrally formed (e.g., cast) as part of the housing **152**, and includes a threaded portion **186** that extends around or circumscribes the electric motor **120** adjacent the output or shaft end thereof. The compression fitting interface **180** further includes a compression seal **188** and a threaded compression screw plug **190**. The compression seal **188** is positioned radially between the electric motor **120** and the housing flange **184**, and the compression seal **188** is seated within a groove **194** formed in the outer surface of the electric motor **120**. The compression seal **188** may be configured to have an elastic fit around the outside of the electric motor **120**. The compression screw plug **190** is axially locked to the electric motor **120** by a retention or locking member **198** (e.g., retaining clip, snap ring), and the compression screw plug **190** is threaded to the housing flange **184** to both establish a connection therebetween and to tighten the compression seal **188**. As can be appreciated from FIGS. **4** and **5**, the compression screw plug **190** can have external threads **202** engageable with the internally threaded portion **186** of the flange **184**. However, it is also conceived to reverse the threads on these parts. The locking member **198** is illustrated as a snap ring, an outside of which is received within a groove **206** on the inside of the compression screw plug **190** and an inside of which is received within a groove **208** on the outside of the electric motor **120**. Due to the engagements provided by the locking member **198**, increasing the threaded engagement between the compression screw plug **190** and the housing flange **184** by tightening the compression screw plug **190** pulls the electric motor **120** into the housing **152** along the axis A.

(18) The tightening the compression screw plug **190** causes a wedge action between the

compression seal **188** and an interior seal surface **210** of the housing **152**. The radially outer surface of the compression seal **188** can have a frustoconical shape following a revolved line segment that forms an acute angle with the central axis A. The interior seal surface **210** can be substantially complementary such that the seal connection becomes increasingly tighter as the compression screw plug **190** is tightened into the housing **152**. The compression screw plug **190** can be provided with a portion that axially abuts an enlarged end of the compression seal **188**. As shown in FIG. **6**, the exterior profile of the compression screw plug **190** can be provided with a plurality of wrench flats **214** (e.g., an eight-sided profile) for tightening and loosening operations to be performed by a tool (e.g., wrench, not shown) applied generally perpendicular to the axis A. As will be understood by one of ordinary skill in the art, such a tool operates about the axis A with leverage away from the axis A.

(19) With a single threaded joint about the central axis A, as opposed to an array of axial fasteners coupling the electric motor **120** and the housing **152** about a prescribed bolt pattern, the compression fitting interface **180** does not control or set a prescribed orientation of the motor **120** about the axis A in relation to the housing **152** and thus the steering rack **24**. However, controlling this orientation or "clocking" of the motor **120** can be desirable in some constructions. For example, it may be desirable or necessary to clock the motor **120** in a prescribed rotational orientation so as to present the electrical connector(s) **146** into a position that enables a connection and/or enables access for field service. In conjunction with the compression fitting interface **180**, which is situated around the motor **120**, an anti-rotation interface is separately formed between the axial end of the motor **120** and the interior of the housing **152**. In particular, the anti-rotation interface includes complementary shapes in an arrangement that renders the electric motor **120** capable of being assembled in a single predefined orientation with respect to the housing **152** in a so-called "poka-yoke." As shown in FIGS. **4-6**, the motor **120** can include a number of studs or male projections **216** (e.g., a plurality of different size and/or shape) and the housing interior can include a number of recesses or female receptacles **218** corresponding to the male projections **216**. Without the prescribed orientation, the projections **216** and the receptacles **218** do not mate, and assembly of the compression screw plug **190** is prevented. The projections **216** and the receptacles **218** can be provided in a regular or irregular array when viewed along the axis A, and one exemplary array pattern is shown in the axial end view of the motor **120** presented in FIG. **6**.

(20) FIG. **7** illustrates an alternate embodiment in which the axial end of the motor **120′** includes at least one projection **216** and at least one receptacle **218**. Although not shown, it will be understood that the illustrated motor **120′** is configured for use with an alternate housing, the interior of which also includes at least one projection and at least one receptacle for complementing the structures provided on the end of the motor **120′**. In yet other embodiments, the motor can have just one or more receptacles, without any projections, and the mating housing interior can have just one or more projections. In some constructions, a series of motors can be manufactured with varying axial end configurations (e.g., anti-rotation interface) corresponding to differences between the motors, and in some cases directly linked to compatibility between the motors and different steering racks and/or different mechanical couplings to the steering rack. In this way, the various motors are mechanically "coded" to be capable of assembly with only the prescribed downstream mechanism. FIG. **7** illustrates for example that the motor **120′** can be of a different class than the motor **120** as observed here by its shorter axial length. The two motors **120**, **120′** may be physically interchangeable aside from the different axial end interfaces, such that the difference in axial end interfaces avoids the possibility that one is accidentally assembled with a steering rack for a vehicle in which is not suitable as determined by the manufacturer, and which may lead to poor performance or inoperability.

(21) FIGS. **8-10** illustrate a few different embodiments for enhancing the sealing structure at the compression fitting interface **180**. In general, these features can be provided in the compression seal **188**, but may alternately be provided in the interior seal surface **210** of the housing **152**. FIGS.

8 and **9** illustrate exemplary ribbing whereby multiple separate seals can be formed in series along the axial direction of the compression seal **188**. FIG. **10** illustrates an exemplary honeycomb seal surface in which multiple walls are provided in a polygonal pattern. These are some examples of providing redundant seals. However, in addition or in lieu of these examples, sealing redundancy can be provided by one or more beads of sealant (e.g., RTV silicone sealant) applied along the compression fitting interface **180**.

(22) FIG. **11** is a partially exploded assembly view of an EPS system **300** according to another embodiment. For the sake of simplicity, the EPS system **300** is shown with the same SCU as the preceding embodiment although it will be understood that the structure of the motor **120** and/or the electronic control unit **144** can take a variety of forms. Similar parts are labeled with consistent reference numerals. In the embodiment of FIG. **11**, the mechanical coupling between the electric motor **120** and the steering rack **24** includes a belt drive like that of FIGS. **2** and **3**. The mechanism includes a toothed disc **328** meshed with a flexible belt **332** to drive a secondary toothed disc **336** for rotating the ball recirculating nut **340** to drive axial movement of the steering rack **24** along the axis B. In other words, the EPS system **300** is of the axial parallel actuation type. The toothed disc **328** is pressed onto an intermediate shaft **330** that is positioned along the axis A of the motor output shaft **126**, but separate therefrom. The motor output shaft **126** and the intermediate shaft **330** can be locked for co-rotation by the collar **176**. The intermediate housing **352** is provided between the SCU and the gearbox cover **48** that encloses the ball recirculating nut **340** and a portion of the steering rack **24**. The intermediate housing **352**, which is partially cutaway in FIG. **11** encloses the flexible belt **332** and the toothed discs **328**, **336**. Within the housing **352**, a pair of bearings **372** support the intermediate shaft **330** at opposite axial ends thereof. The SCU is mated with the intermediate housing **352** by the compression fitting interface **180** including the compression seal **188**, the compression seal plug **190**, and a housing flange **384** like the flange **184** of the housing **152** described above. Thus, the motor **120** (and SCU overall) is releasably secured and sealed without the use of threaded fasteners that extend parallel to the axis A of the electric motor **120**. The operating tension in the flexible belt **332** is retained even when the SCU is removed (e.g., for service or replacement), since the toothed disc **328** remains in place, fully supported by the intermediate shaft **330** and in turn by the intermediate housing **352** through the bearings **372**. The intermediate shaft **330** can be eccentrically mounted within the housing **352** to adjust tension in the belt **332**. In other constructions, a separate belt tensioner can be provided in the intermediate housing **352** between the toothed discs **328**, **336**.

(23) In some constructions, the EPS systems **100**, **300** can be provided in a heavy duty vehicle engineered for an extended service life as compared to a regular passenger vehicle, and the EPS systems **100**, **300** are intended to be serviceable by replacement of the SCU. Such a replacement service can be carried out with the EPS systems **100**, **300** otherwise fully installed in the vehicle. In addition to not requiring belt tensioning as part of the SCU replacement service (which in and of itself reduces time and cost associated with the service for an axial parallel actuation system using a belt), the SCU can be removed from the housing **152** or **352** by loosening a single joint or fastener that extends around or circumscribes the output end of the electric motor **120**. A required tool can be brought into an operational configuration with the joint by movement in a direction perpendicular to the motor axis A and can operate at just one side of the motor **120**, eliminating the need to access multiple fastener positions and eliminating the need to manipulate a tool oriented parallel to the motor axis A.

(24) Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects of the invention as described.

Claims

1. An electric power steering system comprising: an electric motor; a steering rack drivable along a steering rack axis with power from the electric motor; a mechanical coupling between the electric motor and the steering rack for transmitting power from the electric motor to the steering rack, wherein the mechanical coupling is enclosed within a housing; and a compression fitting interface coupling the electric motor and the housing, the compression fitting interface disposed adjacent an axial end of the electric motor at which the mechanical coupling is provided.
2. The electric power steering system of claim 1, wherein the mechanical coupling includes a first toothed disc drivable from an output shaft of the electric motor, a flexible belt drivable from the first toothed disc, and a second toothed disc drivable from the flexible belt.
3. The electric power steering system of claim 2, wherein the output shaft is axially releasable from the first toothed disc, the first toothed disc being supported in the housing to maintain tension in the flexible belt regardless of whether the electric motor is coupled to the housing.
4. The electric power steering system of claim 1, wherein the axial end of the electric motor mates axially to a complementary portion of the housing without an axially interposed seal.
5. The electric power steering system of claim 1, wherein the compression fitting interface includes a compression seal positioned radially between the electric motor and a flange of the housing, and a compression screw plug axially locked to the electric motor and threaded to the housing flange to axially compress the compression seal.
6. The electric power steering system of claim 5, wherein the compression screw plug is axially locked to the electric motor by a lock ring seated into a groove formed in the electric motor.
7. The electric power steering system of claim 5, wherein the compression seal is seated within a groove in an outer surface of the electric motor.
8. The electric power steering system of claim 1, wherein the housing and the electric motor are axially coupled exclusively by the compression fitting interface.
9. The electric power steering system of claim 1, wherein an anti-rotation interface is formed separately from the compression fitting interface between the axial end of the electric motor and an interior of the housing.
10. The electric power steering system of claim 9, wherein the anti-rotation interface includes complementary shapes in an arrangement that renders the electric motor capable of being assembled in a single predefined orientation with respect to the housing.
11. The electric power steering system of claim 1, wherein the mechanical coupling includes a worm drivable from the electric motor, a helical gear wheel drivable from the worm, and a drive pinion drivable from the helical gear wheel to drive the steering rack.
12. An electric power steering system comprising: an electric motor having an output shaft; a steering rack drivable along a steering rack axis with power from the electric motor; a belt coupled between the electric motor and the steering rack for transmitting power of the electric motor to the steering rack, wherein the belt is enclosed within a belt housing and stretched to an operating belt tension by a first tooth disc and a second tooth disc; and a boltless mounting interface securing the electric motor and the belt housing, the boltless mounting interface comprising a compression interface, the compression interface further including a compression seal positioned radially between the electric motor and a flange of the housing and a compression screw plug axially locked to the electric motor and threaded to the housing flange to axially compress the compression seal, wherein the output shaft is axially releasable from the first toothed disc, the first toothed disc being supported in the belt housing to maintain the operating belt tension regardless of whether the electric motor is coupled to the housing.
13. The electric power steering system of claim 12, wherein the compression screw plug is axially locked to the electric motor by a lock ring seated into a groove formed in the electric motor.
14. The electric power steering system of claim 12, wherein the housing and the electric motor are axially coupled exclusively by the compression fitting interface.

15. The electric power steering system of claim 12, wherein the compression seal is seated within a groove in an outer surface of the electric motor.

16. The electric power steering system of claim 12, wherein an axial end of the electric motor mates axially to a complementary portion of the housing without an axially interposed seal.

17. The electric power steering system of claim 12, wherein an anti-rotation interface is formed between an axial end of the electric motor and an interior of the housing.

18. The electric power steering system of claim 17, wherein the anti-rotation interface includes complementary shapes in an arrangement that renders the electric motor capable of being assembled in a single predefined orientation with respect to the housing.