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(54) Abstract Title
Flexible coupled electric power assist steering system

(57) An electric power assist steering system comprises an electric motor 28 whereby said electric motor 28 is positioned remotely from steering mechanism 20. The electric motor 28 is coupled to the steering mechanism 28 by a flexible coupling 26, 60, where said flexible coupling comprises a flexible shaft 62, a flexible sleeve / sheath 64, and connection means 66, 68 at the end of flexible coupling 26, 60 for connection to electric motor 28 and steering mechanism 20. The present invention increases engine compartment utilization efficiency and allows car manufacturers and mechanics to have easier access to the steering motor in case of motor malfunction or during installation.

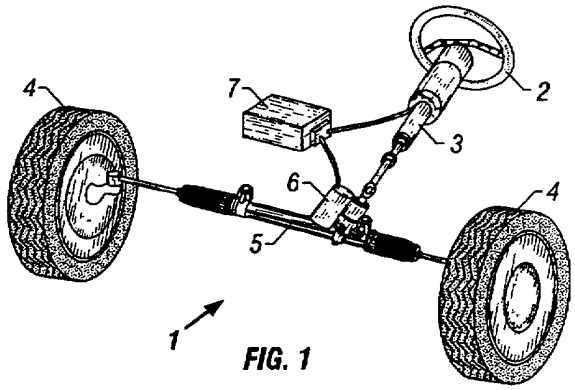

FIG. 1

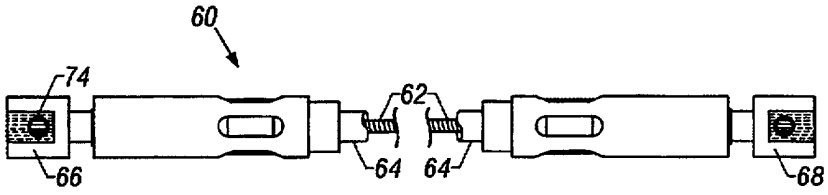

FIG. 6

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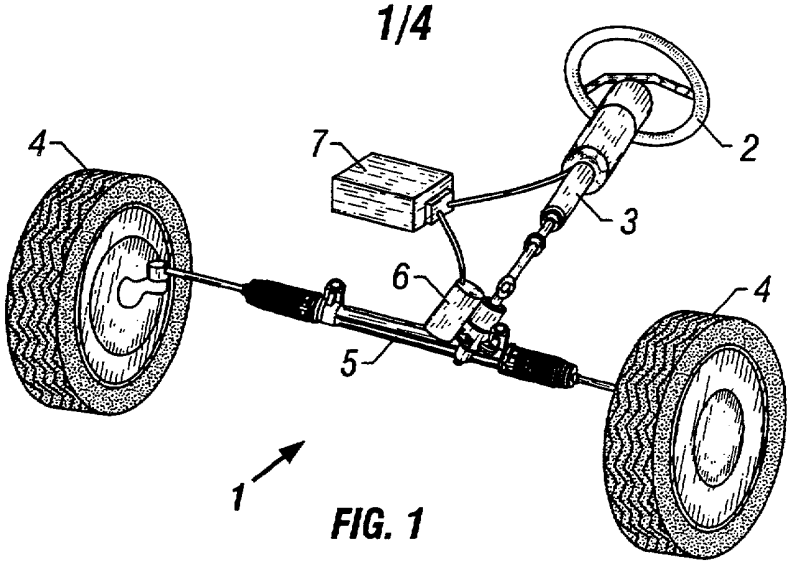

FIG. 1

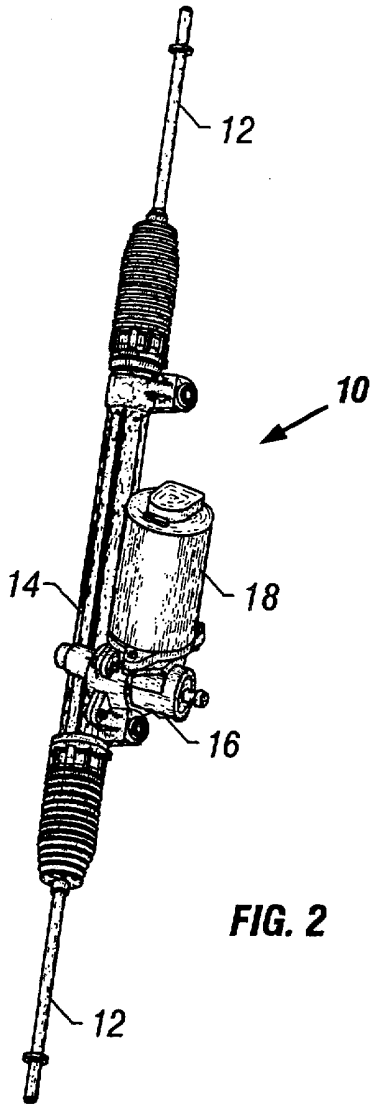

FIG. 2

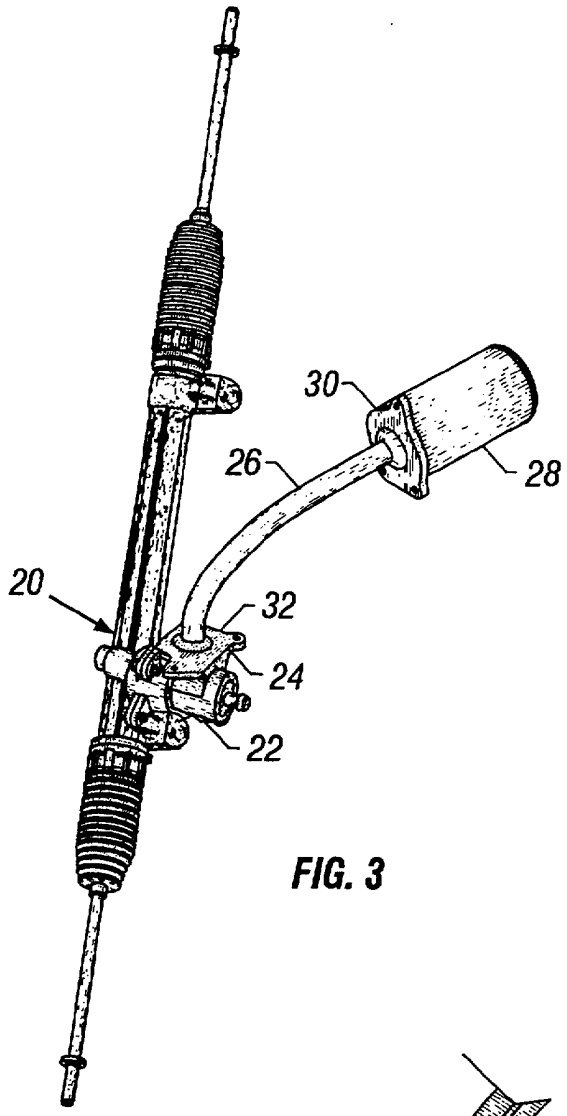

FIG. 3

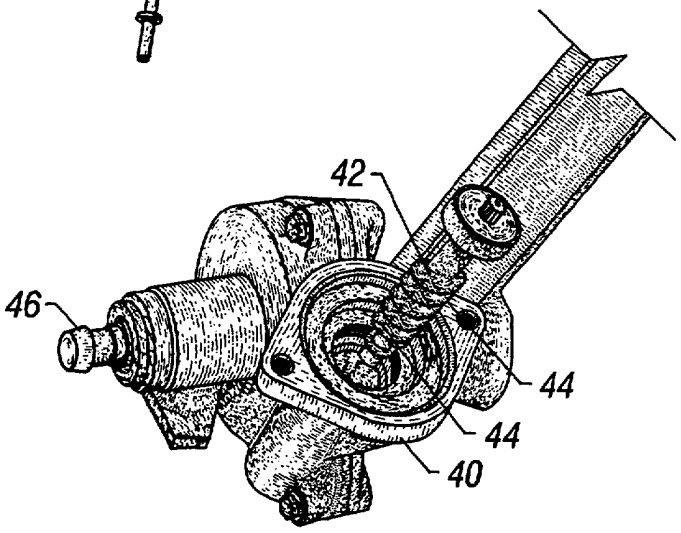

FIG. 4

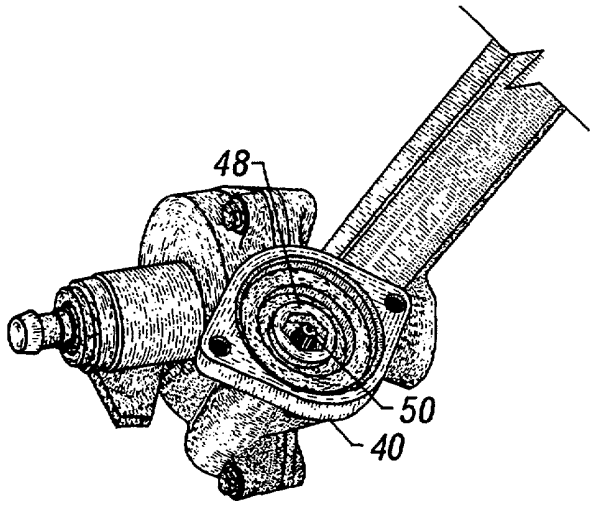

FIG. 5

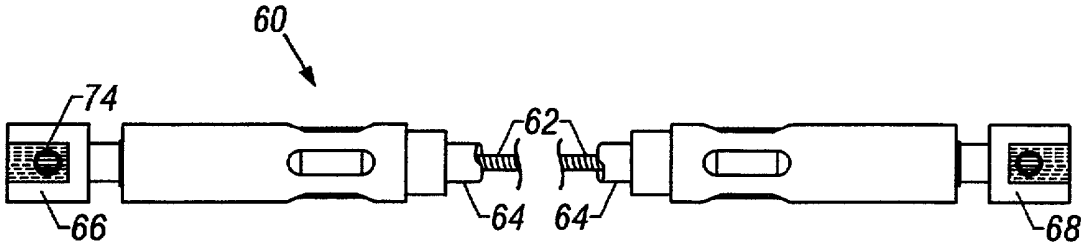

FIG. 6

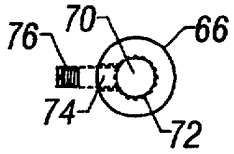

FIG. 7

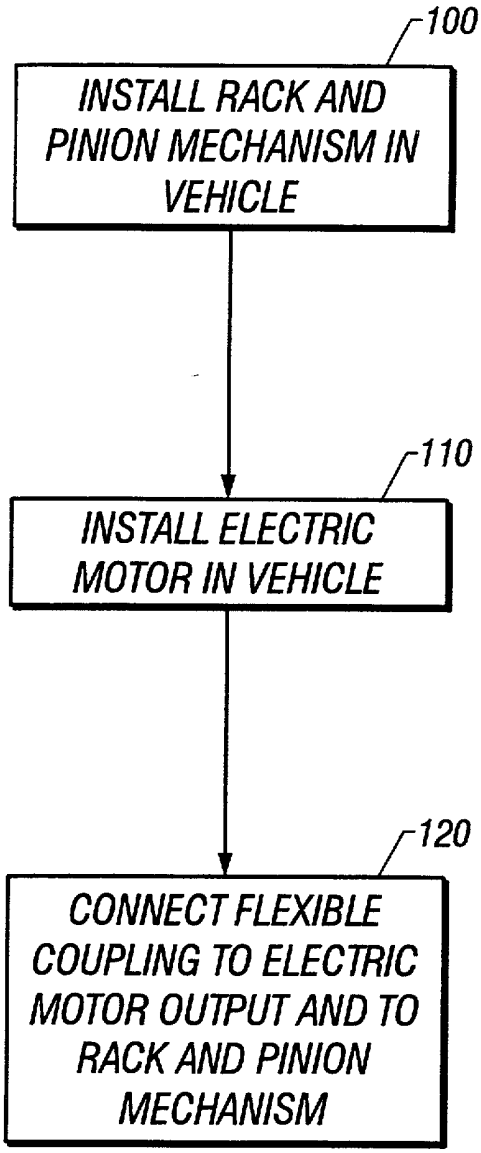
100
INSTALL RACK AND PINION MECHANISM IN VEHICLE
110
INSTALL ELECTRIC MOTOR IN VEHICLE
120
CONNECT FLEXIBLE COUPLING TO ELECTRIC MOTOR OUTPUT AND TO RACK AND PINION MECHANISM

FIG. 8

FLEXIBLY COUPLED ELECTRIC POWER ASSIST STEERING SYSTEM

FIELD OF THE INVENTION

This invention relates generally to the field of vehicle steering systems, and more particularly relates to an electric power assist steering system having an electric motor flexibly coupled to a vehicle steering system.
description of the related art

A TYPICAL STEERING SYSTEM

A typical steering system for a motor vehicle is illustrated in Figure 1. The steering system 1 has rotating steering wheel 2 in the passenger compartment of the vehicle mounted to steering column 3 that is operatively connected to wheels 4 via steering assembly 5. In order to reduce the amount of driver effort (i.e., torque) that is required to rotate the steering wheel, many steering systems include a power-assisted actuator. The actuator assists the operator with rotation of the steering wheel to overcome opposing forces such as road load forces on the road wheels and friction forces in the steering assembly. The amount of power assistance generally varies depending on the speed of the vehicle and the amount of effort applied by the vehicle operator to the steering wheel. Conventional power assist steering systems typically employ either hydraulic power assist or electric power assist mechanisms. Electric power assist mechanisms are being used in an increasing number of

vehicles due to their reduced size and higher energy efficiency than hydraulic mechanisms.

ELECTRIC POWER ASSIST SYSTEMS

An electric power assist steering (EPAS) system employs an electric motor for applying a controlled amount of torque to the steering assembly to assist the operator with rotation of the steering wheel. For example, the system illustrated in Figure 1 includes electric motor 6 for power assist, and controller 7. The steering assembly may be a rack and pinion type that converts angular rotation of the steering wheel into a sliding motion of a rack to steer the wheels. The rack interacts with teeth on an assist pinion that is driven by the output shaft of motor 6 in response to signals from controller 7. The signals from controller 7 are designed to provide a relatively constant torque at the driver pinion.

An example of an EPAS rack and pinion assembly 10 is illustrated in Figure 2. Inner tie rods 12 are connected to a rack and pinion mechanism contained within housing 14. Gear box 16 contains a gear reduction mechanism for the assist pinion. Electric motor 18 is rigidly mounted to gear box 16 to power the assist pinion via the gear reduction mechanism. The motor output shaft directly connects to an input shaft, which may be implemented as a worm gear shaft, in the gear reduction mechanism. A driver pinion torque sensor, as well as various other sensors, may also be included, but the driver pinion and sensors

are not shown to simplify the present description. The measured torque at the driver pinion serves as an approximation of the input torque applied to the steering wheel by the vehicle operator and is commonly used to determine the amount of torque assist to be provided by the electric motor to the assist pinion. Further information about electric power assist steering systems can be found in various patents and literature references, including but not limited to U.S. Patent 5,743,352, to Miller et al., and U.S. Patent 6,250,419, to Chabaan et al., both of which are incorporated by reference as if reproduced in full herein.

Concerns over fuel efficiency have led to the production of smaller vehicles and/or vehicles with more aerodynamic shapes to reduce wind resistance. Due to limitations on reducing the size of the passenger compartment and concerns about passenger compartment comfort, the size of vehicle engine compartments has been reduced and their shape varied to accommodate smaller vehicle sizes and/or new vehicle body designs. The demand for more features while maintaining or increasing vehicle performance have led to an increasing number of components in smaller vehicle engine compartments which have various shapes.

An electric power assist steering system offers variable assist capabilities, more efficient energy consumption, reduced mechanism complexity, increased reliability, and responsive on-demand steering assist, as well as other advantages. Conventional steering systems and components

are available from TRW, having facilities in Livonia Michigan, USA, Delphi Automotive Systems, having facilities in Saginaw, Michigan, USA, and NSK Ltd., having offices in Tokyo, Japan. However, the electric motor increases the size of the system, and rigid attachment of the electric motor to the rack and pinion assembly leaves little flexibility for more efficient engine compartment design and component placement. For example, the typical steering gear has a length of about 1520 mm, inclusive of the tie rods, while a typical power steering motor has a length of at least about 150 mm and a diameter of at least about 100 mm. A conventional power steering system constructed in this manner makes an unwieldy combination. Further, the bulky projection created by the motor rigidly mounted to the assembly makes it more difficult to work on, install, or remove the engine, steering system or other vehicle components in the engine or power source compartment.

As used herein, engine compartment shall refer to the vehicle compartment for an internal combustion engine power source, hybrid internal combustion engine with electric motor power source, or other vehicle power source type.

Accordingly, it is desired to provide an electric power assist steering system that increases the engine compartment utilization efficiency while also increasing the ease of repair, installation, and removal of engine, steering system and other vehicle components in the engine

compartment.

SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention, a steering system and method of installing a power assist steering assembly in a vehicle are disclosed. According to one aspect of the present invention, an electric power assist steering system is provided in which an electric motor is operatively engaged via a flexible coupling with the remainder of the steering system for supplying torque assist. In another aspect, a motor for power assist steering systems is disclosed having a rotating output shaft and a flexible shaft connected thereto for transferring power. A method of installing a steering system in a vehicle is also disclosed wherein the electric motor is installed independently of and then flexibly coupled to the remaining steering system components. The electric motor output shaft is located at a remote location from the pinion shaft or input shaft of the pinion gear reduction mechanism. The steering system, motor, and method of the present invention provide for greater flexibility in engine compartment design and component placement efficiency, and facilitate repair, installation, and removal of engine and steering system components.

These and other features, advantages and objects of the present invention will be further understood and appreciated by those skilled in the art by reference to

the following specification, claims and appended drawings. It is to be understood that both the preceding summary and the detailed description that follows are intended merely to be exemplary and to further explain the invention claimed. The invention may be better understood by reference to the following detailed description read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a typical vehicle steering system.

Figure 2 illustrates a rack and pinion steering mechanism of an electric power assist steering system, in which the electric motor is rigidly attached to the assist pinion gear reduction mechanism.

Figure 3 illustrates an embodiment of a rack and pinion steering mechanism of an electric power assist steering system of the present invention, in which the electric motor is flexibly coupled to the assist pinion gear reduction mechanism.

Figure 4 is an exploded perspective view of an embodiment of an assist pinion gear reduction mechanism housing, showing the worm drive gear detached therefrom.

Figure 5 is a perspective view of an embodiment of an assist pinion gear reduction mechanism housing, showing the worm drive gear inserted therein with its splined end projecting therefrom.

Figure 6 is a side elevation view of the end portions of an exemplary coupling for use with the present invention, in which a portion of the casing has been cut-away to reveal the flexible shaft.

Figure 7 is a cross-sectional end view of the end fitting

of the coupling of Figure 7 shown in exploded relationship to a set screw.

Figure 8 is a flow chart for an exemplary method of installing an electric power assist steering system in a vehicle in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of the present invention may be better understood with reference to Figure 3. Rack and pinion mechanism 20, such as that shown in Figure 2, includes assist pinion gear reduction housing 22 that includes coupling fitting 24 for coupling 26. Coupling 26 couples electric motor 28 to the assist pinion gear reduction mechanism. In this embodiment, a conventional electric motor used in electric power assisted steering mechanisms and a conventional assist pinion gear reduction mechanism and housing are used. Therefore the bolt holes on and dimensions of flanged plate 30 of the motor housing correspond to those of flanged plate 32 on gear reduction mechanism housing 22.

It has been surprisingly discovered that the assist motor can be remotely attached by a flexible coupling to the assist pinion without a substantial decrease in performance of the steering system.

In a preferred embodiment, coupling 26 includes an outer flexible sleeve or conduit that contains a flexible shaft.

The flexible shaft is connected to the motor output shaft at one end and to the gear reduction mechanism input shaft at its opposite end. The flexible shaft may be formed of steel or synthetic fiber that minimizes the loss of torque between the motor and pinion gear mechanism despite being flexible. Non-limiting examples of flexible couplings suitable for use with the present invention can be obtained from Motion Industries of Wichita Falls, TX, and Dearborn, MI, USA, and Stock Drive Products/Sterling Instrument of New Hyde Park, NY, USA. In addition to flexible shafts, it is contemplated that the electric motor may be coupled to the steering system via a single or double universal jointed shaft, in which the shaft has at least two rigid linear steel segments connected via at least one universal joint. A non-limiting example of a source for a suitable assist motor is Visteon Global Technologies, Inc. of Dearborn, Michigan, USA or affiliate thereof, and a non-limiting example of a source for an assist pinion gear reduction mechanism is Nissei Corporation, Japan.

With reference to Figure 4, an example of an assist pinion gear reduction mechanism suitable for use with the present invention is illustrated. Gear reduction housing 40 provides for insertion of worm drive shaft 42. Worm drive shaft 42 includes worm screw threads 44 that engage gears in housing 40. Rotation of worm drive shaft 42 leads to rotation of assist pinion shaft 46.

With reference to Figure 5, worm drive shaft 42 is

rotatably mounted in housing 40 by bolt 48. Shaft 42 may include threads on its outer perimeter, or some other attachment mechanism for connection to the sleeve or outer conduit of flexible coupling 26. Worm drive shaft 42 preferably includes a splined hub 50 for connection to a corresponding fitting on the end of the flexible coupling shaft. A similar splined hub on the electric motor output shaft is connected to a corresponding fitting on the motor end of the flexible coupling shaft in like fashion.

AN EXEMPLARY FLEXIBLE COUPLING

With reference to Figure 6, an exemplary embodiment of a flexible coupling for use with the present invention is illustrated. Flexible shaft 62 is contained within flexible sleeve 64, the latter being partially cutaway to show shaft 62 contained therein. Shaft 62 is continuous, but shown in cut and truncated form to facilitate illustration. Shaft 62 may have a length ranging from about 1 inch up to about 48 inches. However, in a preferred embodiment, shaft 62 is about 24 inches or less in length. Suitable flexible shafts are made of steel, and have diameters ranging from about 0.1 inch to about 0.75 inch depending on the operating requirements. In a preferred embodiment, the shaft has a diameter of about 0.25 inches for use in small to mid-sized cars. Larger diameter shafts may be required for larger vehicles.

Flexible sleeve 64 may be formed of vinyl-covered steel, and its diameter will depend in part on the diameter of

shaft 62. For example, the diameter of shaft 62 may be ½ inch when the shaft is ¼ inch or less in diameter. Sleeve 64 may contain bearings to prevent wear upon contact with shaft 62 when it is rotating.

End fittings 66 and 68 are bonded to the ends of shaft 62. With reference to Figure 7, a cross sectional end view of end fitting 66 is illustrated. Fitting 66 includes a generally cylindrically shaped opening 70 which may be placed over the input hub of a power steering gear reduction mechanism, such as hub 50 in Figure 5. Fitting 66 includes splines 72 on its interior wall designed to engage corresponding splines on an input hub. However, other gripping mechanisms may be employed or the interior wall of fitting 66 may be smooth.

A bore 74 is provided in fitting 66 to provide for a set screw, such as screw 76. Use of a set screw may require that the input hub on the power steering gear mechanism be sufficiently long to permit tightening of set screw 76 to the hub. More than one bore may be provided for a plurality of set screws, particularly for larger diameter shafts that may encounter high torque demands. Fittings 66 and 68 may be of plated steel or other suitable material. The sheathing for the flexible coupling may have an extended cowl at either end to cover the rotating fittings 66 and 68.

In general, the minimum operating radius of curvature for the flexible shaft increases with shaft diameter. As

radius of curvature increases, the dynamic torque capacity of the shaft increases. Thus, it is preferred that the electric motor output shaft be aligned with the input hub of the power steering input shaft or gear in order to optimize the radius of curvature to the performance requirements. Performance data for exemplary flexible shafts is provided in Table 1 below.

A preferred source for flexible shafts is Stock Drive Products/Sterling Instrument of New Hyde Park, NY, USA. Non-limiting examples include Catalog Numbers A 7Z10-N24433, A 7Z10-N24533, A 7Z10-N36533, A 7Z10-N30633, A 7Z10-N36633, A 7Z10-N24833, A 7Z10-N36833. As noted above, a single or double universal jointed shaft may be used in place of the flexible shaft, preferably including a flexible rubber sleeve over the joints. A preferred double universal jointed shaft may provide a maximum working angle of approximately 70 degrees, and is available from Belden Incorporated, Broadview, Illinois, USA. Non-limiting examples of suitable double universal shafts for use with the present invention include Belden Incorporated part numbers DUJ375, DUJ500, DUJ625, DUJ750, UJ-DD375, UJ-DD500, UJ-DD625 and UJ-DD750.

TABLE 1

PERFORMANCE DATA FOR EXEMPLARY FLEXIBLE SHAFTS

		Dynamic Torque Capacity Winding Direction (lb. In.) Input								
		Radius of Curvature (In.)								
Shaft Diameter (In.)	Minimum Operating Radius (In.)	25	20	15	12	10	8	6	4	Torsional Breaking Load For Straight Shafts, Winding Direction (lb. In.)
0.130	3.0			3.8	3.6	3.4	3.1	2.4	1.7	15
0.150	4.0			5.0	4.7	4.4	3.9	3.1	1.4	24
0.187	4.0		13.5	12.6	11.8	11.0	9.8	7.8	4.0	55
0.250	4.0	25.0	24.0	22.0	21.0	19.0	16.0	12.0		100

In a preferred embodiment, an electric motor is flexibly coupled to a conventional rack and pinion steering mechanism, which is incorporated into a conventional steering system. However, it is envisioned that the present invention may be adapted to column as well as dual pinion steering systems, and to many different vehicle types, such as but not limited to the Ford Focus, Saturn SUV, and Honda S2000.

EXEMPLARY METHODS FOR INSTALLING AN ELECTRIC POWER ASSIST STEERING SYSTEM

In an embodiment, a power assist steering system is installed in a vehicle by installing the electric motor independently of the rack and pinion mechanism and/or gear reduction mechanism. For example, with reference to Figure 8, in a first step 100 of an exemplary method, the rack and pinion mechanism is installed. In a second step 110, an electric motor suitable for providing power assist to the rack and pinion mechanism is installed. In a third step 120, the electric motor output is coupled to the input of the rack and pinion mechanism by connection of the flexible coupling to the electric motor output and to the input of the rack and pinion mechanism.

Preferably, the electric motor is mounted away from heat and road splash, and the motor output shaft remains as "in-line" as possible with the power assist pinion input. In general, the higher the torque requirements, the more the motor output shaft should be in linear alignment with

the power steering input shaft hub. By placing the motor closer to the electric power source, additional economies can be obtained. The flexible coupling provides for numerous variations in the method of installation, which may be optimized depending on the vehicle, engine, and other considerations. Some exemplary methods are described in Table 2 below.

TABLE 2
Exemplary Methods for installing an electric power assisted steering system of the present invention in a vehicle

STEP	NOTES
Electric Motor Installation	Install a suitable electric assist motor for providing power to a compatible steering mechanism in the desired engine compartment location, preferably away from road splash. The electric motor output shaft preferably faces in the general direction of the location where the steering mechanism is or is to be installed, but at a distance therefrom.
Steering Mechanism Installation	Install a steering mechanism in the desired engine compartment location. The input shaft of the steering mechanism should face in the general direction of the location where the electric power assist motor output shaft is or is to be installed, but is

	remote therefrom. The angle between the steering mechanism input shaft and the electric motor output shaft is preferably less than about 90 degrees, and in an embodiment less than about 15 degrees. This step may be performed before the Electric Motor is installed.
Coupling Electric Motor To Steering Mechanism	The electric motor may be coupled to one end of the flexible coupling prior to its installation. Alternatively, one end of the flexible coupling can be coupled to the steering mechanism input shaft prior to installation of the steering mechanism in the engine compartment. This latter technique may be helpful where the steering mechanism input shaft is hard to reach after installation. Connection of the free end of the coupling is done after both the electric assist motor and steering mechanism are installed in the engine compartment. In an alternative embodiment, the motor and steering mechanism are coupled together prior to installation, with the flexible coupling making it easier to manipulate the entire apparatus into the engine compartment.

As one of skill in the art will recognize, the longer the flexible coupling between the motor output and steering gear input, the greater the potential loss of torque between the motor and input gear. Further, the dynamic torque capacity is lower with a lower radius of curvature, so that the angle and distance between the motor output and steering gear input should be optimized for particular applications. In preferred embodiments, the distance between the motor output and the input gear is less than about 36 inches, and is preferably equal to or less than about 24 inches, and the angle between the motor output and the input gear is less than about 90°, and is preferably less than about 45°. In one embodiment, the flexible shaft is between about 1 inch and about 24 inches in length, and the angle between the motor output shaft and the gear input is between about 0° and about 30°. In another embodiment, the angle between the motor output shaft and the gear input is between about 0 degrees and about 15 degrees. Embodiments also include shafts of 6 inch and 12 inch length.

While embodiments of a new electric power assist steering system and methods of installing same have been disclosed as examples herein, there could be a wide range of changes made to these embodiments without departing from the present invention. For example, it is envisioned that the reduction gear mechanism may be rigidly connected to the electric motor, and the output from the reduction gear mechanism flexibly coupled to an assist pinion input in the same fashion as the electric motor is flexibly coupled

to the assist pinion gear reduction mechanism input shaft described above. Thus, it is intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it be understood that it is the following claims, including all equivalents, which are intended to define the scope of the invention.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately, or in any suitable combination.

The disclosures in United States patent application No. 10/014,688 from which this application claims priority, and in the abstract accompanying this application are incorporated herein by reference.

Claims

1. An electric power assist steering system, comprising an electric motor 28 having an output shaft and a motor housing, and a steering mechanism 20, characterized in that it further comprises a flexible shaft 62 having a first end and a second end, wherein said flexible shaft is operatively coupled to said output shaft at said first end and is operatively coupled to said steering mechanism at said second end.

2. The steering system of claim 1, characterized in that said steering mechanism comprises a rack and pinion mechanism.

3. The steering system of claims 1 or 2, characterized in that said steering mechanism comprises an assist pinion gear mechanism 16, said gear mechanism comprising an input shaft and a gearbox housing 22, wherein said second end of said flexible shaft is operatively connected to said input shaft.

4. The steering system of any one of claims 1 through 3, characterized in that said flexible shaft comprises steel.

5. The steering system of any one of claims 1 through 4, characterized in that it further comprises a flexible sleeve 64 having a motor end and a steering mechanism end, a first coupling at said first end of said flexible shaft and a second coupling at said second end of said flexible

shaft, wherein said flexible sleeve surrounds at least a portion of said flexible shaft, said motor end of said sleeve is connected to said motor housing, said steering mechanism end of said sleeve is connected to said gearbox housing, said first coupling couples said flexible shaft to said output shaft of said electric motor, and said second coupling couples said flexible shaft to said input shaft of said gear reduction mechanism.

6. The steering system of any one of claims 1 through 5, characterized in that said flexible shaft has a length between about 1 inch and about 36 inches, and a diameter between about 0.1 inches and about 0.75 inches.

7. The steering system of any one of claims 1 through 6, characterized in that said flexible shaft includes at least two rigid steel shafts connected by at least one universal joint.

8. The steering system of any one of claims 1 through 7, characterized in that the angle between said input shaft and said output shaft is less than about 90 degrees.

9. The steering system of any one of claims 1 through 7, characterized in that the angle between said input shaft and said output shaft is less than about 15 degrees.

10. The steering system of any one of claims 1 through 9, characterized in that said flexible shaft has a dynamic torque capacity between about 1.4 pound inch and about 25

pound inch.

11. A method for installing an electric power assisted steering system in a vehicle characterized by the steps of:

installing in a vehicle an electric motor for providing power to a steering mechanism, the electric motor having an output shaft, and

installing in the vehicle a steering mechanism that can be operatively connected to said electric motor, wherein the steering mechanism has an input shaft, said electric motor and said steering mechanism being installed independently of each other and said electric motor being installed at a location wherein the output shaft of the electric motor is at a remote location from said input shaft.

12. The method of claim 11, characterized in that it further comprises the step of connecting said electric motor output shaft to the steering mechanism input shaft via a flexible shaft.

13. The method of claim 11 or 12, characterized in that said flexible shaft comprises steel.

14. The method of any one of claims 11 through 13, characterized in that the steering mechanism and motor are installed so that the angle between said input shaft and said output shaft is less than about 90 degrees.

15. The method of any one of claims 11 through 13,

characterized in that the steering mechanism and motor are installed so that the angle between said input shaft and said output shaft is less than about 15 degrees.

Amendments to the claims have been filed as follows

Claims

1. An electric power assist steering system, comprising an electric motor having an output shaft and a motor housing, and a steering mechanism, characterized in that it further comprises a flexible shaft having a first end and a second end, wherein said flexible shaft is operatively coupled to said output shaft at said first end and is operatively coupled to said steering mechanism at said second end; wherein said flexible shaft has a length between 1 inch (25.4 mm) and 36 inches (914.4 mm), and a diameter between 0.1 inches (2.54 mm) and 0.75 inches (19.05 mm).

2. The steering system of claim 1, characterized in that said steering mechanism comprises a rack and pinion mechanism.

3. The steering system of claims 1 or 2, characterized in that said steering mechanism comprises an assist pinion gear mechanism, said gear mechanism comprising an input shaft and a gearbox housing, wherein said second end of said flexible shaft is operatively connected to said input shaft.

4. The steering system of any one of claims 1 through 3, characterized in that said flexible shaft comprises steel.

5. The steering system of any one of claims 1 through 4, characterized in that it further comprises a flexible

sleeve having a motor end and a steering mechanism end, a first coupling at said first end of said flexible shaft and a second coupling at said second end of said flexible shaft, wherein said flexible sleeve surrounds at least a portion of said flexible shaft, said motor end of said sleeve is connected to said motor housing, said steering mechanism end of said sleeve is connected to said gearbox housing, said first coupling couples said flexible shaft to said output shaft of said electric motor, and said second coupling couples said flexible shaft to said input shaft of said gear reduction mechanism.

6. The steering system of any one of claims 1 through 5, characterized in that said flexible shaft includes at least two rigid steel shafts connected by at least one universal joint.

7. The steering system of any one of claims 1 through 6, characterized in that the angle between said input shaft and said output shaft is less than about 90 degrees.

8. The steering system of any one of claims 1 through 6, characterized in that the angle between said input shaft and said output shaft is less than about 15 degrees.

9. The steering system of any one of claims 1 through 8, characterized in that said flexible shaft has a dynamic torque capacity between 1.4 pound inch (0.16 Nm) and 25 pound inch (2.82 Nm).

10. An electric power assist steering system substantially as herein described with reference to or as shown in Figures 3, 6 and 7 of the drawings.

11. A method of installing the electric power assisted steering system of claim 1 in a vehicle characterized by the steps of:

installing in a vehicle an electric motor for providing power to a steering mechanism, the electric motor having an output shaft, and

installing in the vehicle a steering mechanism that can be operatively connected to said electric motor, wherein the steering mechanism has an input shaft, said electric motor and said steering mechanism being installed independently of each other and said electric motor being installed at a location wherein the output shaft of the electric motor is at a remote location from said input shaft; and

further comprising the step of connecting said electric motor output shaft to said steering mechanism input shaft via a flexible shaft which has a length between 1 inch (25.4 mm) and 36 inches (914.4 mm), and a diameter between 0.1 inches (2.54 mm) and 0.75 inches (19.05 mm).

12. The method of claim 11, characterized in that said flexible shaft comprises steel.

13. The method of claims 11 or claim 12, characterized in that the steering mechanism and motor are installed so

that the angle between said input shaft and said output shaft is less than 90 degrees.

14. The method of any one of claims 11 through 13, characterized in that the steering mechanism and motor are installed so that the angle between said input shaft and said output shaft is less than 15 degrees.

15. A method of installing the electric power assisted steering system substantially as herein described with reference to the drawings.

Application No: GB 0207865.7
Claims searched: 1 to 10, 12 and 13.

Examiner: Richard C. C. So
Date of search: 17 June 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): B7H (HHT); F2U (U13A).

Int Cl (Ed.7): B62D (5/04); F16C (1/00, 1/02, 1/06, 1/08, 1/26).

Other: Online: EPODOC, JAPIO, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	US 3940945 A	(HARDMARK). See all figures especially figures 3, 7 and 8 in particular to flexible inner cable 5 with flexible sheath 8 and 12 and coupling 15, and column 3 lines 23 to 28.	5.
Y	US 3927899 A	(BOUGH). See whole document especially figures 1, 2 and 4 in particular to flexible inner cable 72, flexible sleeve 64, input coupling 38 and output coupling 50, column 3 lines 51 to 63, and column 4 lines 41 to 62.	5.
X, Y	JP 6293268 A	(KAYABA INDUSTRY CO. LTD.). See abstract and figure 1 in particular to flexible shaft 27, motor 21, pinion 3, rack 5, assist pinion gear mechanism 29	X = 1 to 4, 8, 9, 12 and 13. Y = 5.
X, Y	JP 6239250 A	(KAYABA INDUSTRY CO. LTD.). See abstract and figure 2 in particular to flexible shaft 9, motor M, and steering mechanism 6.	X = 1 to 4, 8, 9, 12 and 13. Y = 5.

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

Application No: GB 0207865.7 **Examiner:** Richard So
Claims searched: 11 to 15 **Date of search:** 21 October 2002

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): B7H (HHT).

Int Cl (Ed.7): B62D (5/04); F16C (1/02).

Other: Online: EPODOC, JAPIO, WPI, TXTEP, TXTGB, TXTUS, TXTWO.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X, Y	US 5979587 A	(LIUBAKKA et al.). See figure 2 in particular to remotely positioned motor 32 and steering mechanism.	X = 11, 14 and 15. Y = 12 and 13.
X, Y	US 4703821 A	(SHIMIZU). See figure 1 in particular to remotely positioned motor 5 and steering mechanism.	X = 11, 14 and 15. Y = 12 and 13.
X, Y	US 4743817 A	(SHIMIZU). See figures 5 and 7 in particular remotely positioned motors 100, 101 and steering mechanism 125, and column 8 lines 25 to 68.	X = 11, 14 and 15. Y = 12 and 13.
Y	US 3940945 A	(HARDMARK). See all figures especially figures 3, 7 and 8 in particular to flexible inner cable 5 with flexible sheaths 8 and 12 and coupling 15, and column 4 lines 9 to 25.	12 and 13.
Y	US 3927899 A	(BOUGH). See whole document especially figures 1, 2 and 4 in particular flexible inner cable 72, flexible sleeve 64, input coupling 38, output coupling 50, and metallic bodies 34, 120, and column 5 lines 15 to 32.	12 and 13.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Application No: GB 0207865.7
Claims searched: 11 to 15

Examiner: Richard So
Date of search: 21 October 2002

Category	Identity of document and relevant passage		Relevant to claims
X, Y	JP 6293268 A	(KAYABA INDUSTRY CO. LTD.). See abstract and figure 1 in particular to flexible shaft 27, motor 21, pinion 3, rack 5, assist pinion gear mechanism 29	X = 11, 12, 14 and 15. Y = 13.
X, Y	JP 6239250 A	(KAYABA INDUSTRY CO. LTD.). See abstract and figures 2 and 3 in particular to flexible shaft 9, motor M, and steering mechanism 6.	X = 11, 12, 14 and 15. Y = 13.

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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.