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10/902,507 29 July 2004 (29.07.2004) US(71) Applicant (for all designated States except US): **TRW AUTOMOTIVE U.S. LLC** [US/US]; 34201 Van Dyke Avenue, Sterling Heights, MI 48311 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **STOLL, Richard, A.** [US/US]; 118 Hawthorn, Royal Oak, MI 48067 (US). **BORZA, John, S.** [US/US]; 54641 Arrowhead, Shelby Township, MI 48315 (US). **GOUR, Richard, E.** [US/US]; 2489 Rocky Top CT., Commerce Township, MI 48382 (US). **OLSEN, William, F.** [US/US]; 1465 Henrietta Street, Birmingham, MI 48009 (US). **KRAUSE, Jeffery** [US/US]; 2665 Shadow Lake Drive, Lake Orion, MI 48360 (US).(74) Agent: **DOUGLAS, V. Pavelko**; Macmillan, Sobanski & Todd, LLC, One Maritime Plaza, 4Th Floor, 720 Water Street, Toledo, OH 43604 (US).

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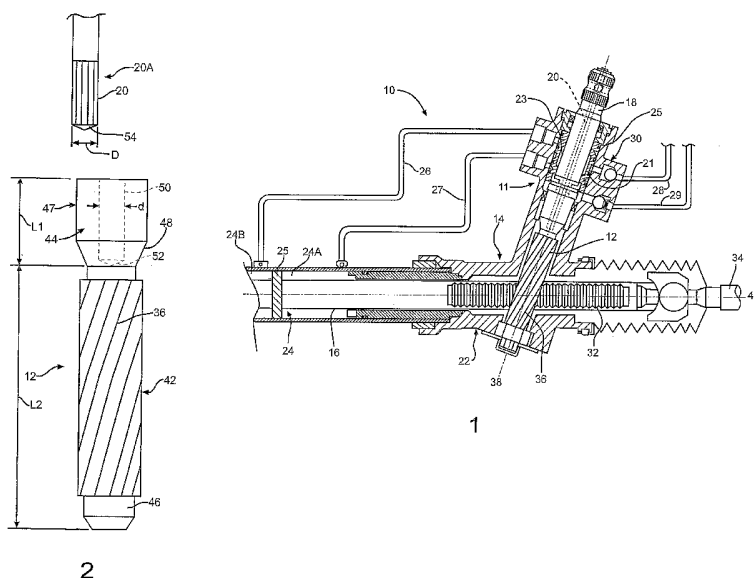
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(54) Title: METHOD FOR FORMING A VALVE ASSEMBLY



(57) Abstract: A method for forming a valve assembly (10) for a rack and pinion steering apparatus. A pinion (12) having a bore (50) formed therein, a torsion bar (20) having an outer diameter, a valve sleeve (21), and an input shaft (18) are provided. The input shaft (18) has a bore (50) and an elongated cavity formed therein. The input shaft has an outer diameter less than an inner diameter of the valve sleeve. The torsion bar is forced into the bore of the pinion to friction weld the torsion bar to the pinion. The valve sleeve is positioned over the torsion bar and pinion, and secured with the pinion. The torsion bar is positioned within the bore of the input shaft such that a first end of the torsion bar is positioned coaxially within the elongated cavity of the input shaft. A locking material is inserted into the elongated cavity to lock the torsion bar and the input shaft together.

TITLE

METHOD FOR FORMING A VALVE ASSEMBLY

BACKGROUND OF THE INVENTION

[0001] This invention relates in general to a rack and pinion steering assembly, and more particularly relates to a method for joining an input shaft, torsion bar and pinion to form a valve assembly for use in such a rack and pinion steering assembly.

[0002] A typical rack and pinion power steering assembly for use in a power-assisted vehicle steering system includes a rack operatively coupled with steerable vehicle wheels and a pinion operatively coupled with a vehicle steering wheel. Teeth on the pinion mesh with teeth on the rack such that rotation of the pinion produces linear movement of the rack, which, in turn, causes the steerable wheels to turn laterally with respect to the vehicle. The pinion is connected at another end with the vehicle steering wheel by an input shaft and a torsion bar.

[0003] Many power-assisted rack and pinion steering assemblies include a valve portion that uses hydraulic power to assist the steering operation of the vehicle. A valve assembly is formed within the valve portion and includes the input shaft, the torsion bar, a valve sleeve and a pinion gear. When the rack and pinion steering assembly is mounted in a vehicle, the input shaft is connected to a steering wheel. Rotation of the steering wheel results in rotation of the input shaft. The input shaft is fixed relative to the end of the torsion bar so that rotation of the input shaft results in rotation of the end of the torsion bar. Torsion of the torsion bar causes a valve core of the valve assembly to move relative to a valve sleeve.

[0004] In a neutral position, hydraulic fluid flows from a source through passages in the valve sleeve. An equal amount of fluid is directed toward opposed passages in the valve sleeve. Since an equal amount of fluid is directed through each passage, the pressure within the system is balanced. When a steering operation is performed, the valve core is rotated relative to the valve sleeve and the valve assembly moves out of

the neutral position, or is actuated, and fluid is directed toward a rack section of the valve assembly. The rack section includes a rack housing, a piston positioned within the rack housing and a rack connected with the piston. The piston and rack are configured for axial movement within the rack housing. The piston divides the rack housing into two chambers so that depending on which way the steering wheel is rotated, fluid can flow to either a left or right chamber to facilitate movement of the rack. A higher pressure in a first chamber relative to the pressure in the second chamber results in a differential pressure that causes the piston to move. When the piston moves, the rack moves and the steerable wheels are turned.

[0005] During movement of the rack relative to the rack housing, interaction of teeth of the rack with teeth of the gear portion of the pinion gear rotates the pinion gear. Rotation of the pinion gear rotates the valve sleeve relative to the valve core. As a result, movement of the rack rotates the valve assembly back into the neutral position. When the valve assembly is in the neutral position, fluid is again directed from the valve sleeve passages to be returned to a reservoir.

[0006] It would be advantageous to develop a method of forming the valve assembly and particularly for joining the components thereof together.

SUMMARY OF THE INVENTION

[0007] The invention relates to a portion of a rack and pinion steering assembly as well as a method for forming a portion of a rack and pinion steering assembly. An input shaft and a torsion bar are provided. The input shaft has a bore and an elongated cavity. The torsion bar has an outer diameter that is about the same as the diameter of the bore of the input shaft. The torsion bar is positioned within the bore and the elongated cavity, thereby forming an annular space between the torsion bar and an inner surface of the elongated cavity. A locking material is inserted into the annular space for locking the input shaft to the torsion bar.

[0008] The invention also relates to a method for forming a portion of a rack and pinion steering assembly where a torsion bar and a pinion gear are provided. The pinion gear has a bore formed therein. The torsion bar is forced into the bore to secure the torsion bar to the pinion.

[0009] The invention also relates to a rack and pinion steering apparatus as well as a method for forming a valve assembly for the rack and pinion steering apparatus. A pinion having a bore formed therein, a torsion bar having an outer diameter, a valve sleeve, and an input shaft are provided. The input shaft has a bore and an elongated cavity formed therein. The input shaft has an outer diameter less than an inner diameter of the valve sleeve. The torsion bar is forced into the bore of the pinion to secure the torsion bar to the pinion. The valve sleeve is positioned over the torsion bar and pinion, and secured with the pinion. The torsion bar is positioned within the bore of the input shaft such that a first end of the torsion bar is positioned coaxially within the elongated cavity of the input shaft. A locking material is inserted into the elongated cavity to lock the torsion bar and the input shaft together.

[00010] Various objects and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiment, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[00011] Fig. 1 is a cross-sectional view of a portion of a rack and pinion steering assembly.

[00012] Fig. 2 is an exploded elevational view of a torsion bar and pinion gear.

[00013] Fig. 3 is an elevational view of the assembled torsion bar and pinion gear according to the present invention.

[00014] Fig. 4 is a partial cut-away view of a portion of an assembled torsion bar and an input shaft assembly according to the present invention.

[00015] Fig. 5 is a cross-sectional view of a portion of a rack and pinion steering assembly schematically illustrating an electronically controlled power assisted steering system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00016] Referring now to the drawings, there is illustrated in Fig. 1 a portion of a hydraulically assisted rack and pinion steering assembly, indicated generally at 10, having a valve assembly 11 in accordance with the present invention. The steering assembly 10 further includes a pinion 12, a housing 14, a rack 16, an input shaft 18, and a torsion bar 20. It can be appreciated that the steering assembly 10 described below could be used in either a hydraulically assisted power steering apparatus or an electronically controlled power steering apparatus.

[00017] The housing 14 has a hydraulic valve section 30 and a transversely extending rack section 22 through which the rack 16 extends. A rack chamber 24 is defined in the rack section 22 of the housing 14. Hydraulic conduits 26 and 27 provide fluid communication between the rack chamber 24 and the valve section 30 of the housing 14. Hydraulic conduits 28 and 29 provide fluid communication between the valve section 30, a power steering pump (not shown) and a reservoir (not shown).

[00018] A piston 25 is connected to the rack 16 and is disposed in the rack chamber 24. The piston separates the rack section 22 into a first chamber 24A and a second chamber 24B. Fluid from the valve section 30 will selectively be supplied to the first chamber 24A or the second chamber 24B depending on the steering maneuver being performed. The rack 16 includes a section having rack teeth 32. The rack teeth 32 are meshed with helical teeth 36 on the pinion 12 inside the housing 14. Opposite ends of the rack 16 are connected with steerable vehicle wheels (not shown) by pivotable tie rods, one of which is shown at 34, as is known in the art. When a steering maneuver is being performed, the pinion 12 rotates about an axis 38, and the rack 16 moves longitudinally along a horizontal axis 40.

[00019] The valve assembly 11 includes several of the components listed above, including the pinion 12, the input shaft 18, the torsion bar 20, and a valve sleeve 21. The valve section 30 communicates with the first chamber 24A through a first two-way hydraulic conduit 26. The valve section 30 communicates with the second chamber 24B through a second two-way hydraulic conduit 27. The valve section 30 receives hydraulic fluid from a reservoir (not shown) and a pump (not shown) through an inlet hydraulic conduit 28. The pump could be a flow-varying pump, and could be driven by an electric motor or by the vehicle engine. An outlet hydraulic conduit 29 exhausts hydraulic fluid from the valve section 30 to the reservoir.

[00020] The valve section 30 operates in response to the rotation of the vehicle steering wheel via the input shaft 18. When the input shaft 18 rotates in a first direction about the axis 38, it rotates slightly relative to the pinion 12. The torsion bar 20 flexes to permit such rotation of the input shaft 18 relative to the pinion 12. The valve section 30 responds to the resulting rotational displacement by opening hydraulic fluid flow paths that extend through the valve section 30 from the inlet conduit 28 to the first two-way flow conduit 26. The input shaft 18 rotates slightly inside of the valve sleeve 21. As the input shaft rotates, a port (not shown) for hydraulic pressure is opened as well as a port returning to the hydraulic pump reservoir. This motion opens and closes various ports to connect the hydraulic conduits 26, 27, 28 and 29. The valve section 30 simultaneously closes the hydraulic fluid flow paths that extend through the valve section 30 from the inlet hydraulic conduit 28 to the second two-way flow conduit 27 to the outlet conduit 29. A resulting flow of hydraulic fluid from the pump, and a resulting hydraulic fluid pressure differential acting against the piston 25, causes the piston 25 and therefore the rack 16 to move to the right, as viewed in Fig. 1, along the axis 40. This causes the steering linkage to steer the vehicle wheels in a first direction. With the torsion bar 20 in a neutral position, the valve section 30 is in a "normally open" position. That is, there is a fluid flow from conduit 28, through the valve sleeve 21 and out of conduit 29. The fluid pressure will be balanced within the rack chamber

24 as will the fluid pressure within conduits 26 and 27. Therefore, when the steering wheel is turned, the valve section 30 becomes further opened, thereby allowing fluid to flow through one of the conduits 26, 27 to the rack chamber 24.

[00021] As the rack 16 moves along the axis 40 with the piston, the helical teeth 36 of the pinion 12 rotate in meshing engagement with the rack teeth 32. The pinion 12 then rotates about the axis 38 relative to the input shaft 18 in a follow-up manner so as to cancel the rotational displacement between the pinion 12 and the input shaft 18. The valve section 30 responds by returning the previously opened hydraulic fluid flow paths (conduit 28 to conduit 26) to a closed position and returns the valve section 30 to its neutral position. This equalizes the hydraulic fluid pressures acting on the piston 25 in the two rack chambers 24A and 24B, and causes the piston 25 and the rack 16 to stop moving along the axis 40.

[00022] When the vehicle wheels are to be steered in an opposite direction, the input shaft 18 is rotated with the steering wheel in an opposite direction about the axis 38, and is again rotated slightly relative to the pinion 12 upon the flexing of the torsion bar 20. The valve section 30 responds by pressurizing the second rack chamber 24B and by simultaneously exhausting the first chamber 24A. The piston 25 and the rack 16 then move axially to the left, as viewed in Fig. 1. A resulting follow-up rotation of the pinion 12 relative to the input shaft 18 causes the valve section 30 again to equalize the hydraulic fluid pressures in the two rack chambers.

[00023] As is also shown in Fig. 1, the valve section 30 includes an "inner" valve core 23, which is an extension of or formed integrally with the input shaft 18, and the "outer" valve sleeve 21, which is part of or connected to the pinion 12. Both the valve core 23 and the valve sleeve 21 have generally cylindrical shapes and are centered on the axis 38. The valve sleeve 21 is formed as a sleeve that fits over the core 23. Therefore, the valve sleeve 21 has an inner diameter that is slightly larger than the outer diameter of the core 23 and therefore, the input shaft 18. The core 23 is defined by a section of the input shaft 18 positioned within the valve sleeve 21. The valve

sleeve 21 is connected with an upper end portion of the pinion 12 by appropriate means, such as for example, by pinning. Accordingly, the core 23 and the valve sleeve 21 rotate relative to each other when the input shaft 18 and the pinion 12 rotate relative to each other. The core 23 and the valve sleeve 21 then vary the hydraulic fluid flow paths extending through the valve section 30 so that certain flow paths become unrestricted and certain flow paths become restricted. Pressurized flows of hydraulic fluid are thereby directed through the valve section 30 between the pump and the rack chambers, as described above.

[00024] A step in assembling these various components in the valve assembly 11 is balancing the hydraulic forces so that the valve section 30 substantially prevents a hydraulic flow when there is no steering maneuver being performed. In the balanced position, the torsion bar 20 is in a neutral position in which there is substantially no torque being applied to the torsion bar 20. Thus, the steering wheel is also in a neutral position. When the torsion bar 20 is in the neutral position, the various flow paths in the valve section 30 will be substantially balanced (and opened between conduit 28 and conduit 29). The purpose for the torsion bar 20 is to essentially return the valve section 30 to the neutral position after a steering maneuver has been performed. The method of assembling the input shaft 18, the torsion bar 20 and the components of the valve assembly 11 will be described in greater detail below.

[00025] A step in the formation of the valve assembly 11 that is typically performed prior to the step of balancing the hydraulic forces in the valve section 30 is the joining together of the pinion 12 and the torsion bar 20. However, it should be appreciated that any of the steps described being performed in the method of joining or assembling the valve assembly 11 according the present invention can be done in any order. It should also be appreciated that the pinion 12 and the torsion bar 20 can be assembled in any suitable manner. In one embodiment, the torsion bar 20 and the pinion 12 are joined together by a friction welding process. In an alternate, and preferred

embodiment, the torsion bar 20 and pinion 12 are joined together by a high velocity insertion method.

[00026] Illustrated in Fig. 2, there is shown an exploded view of a portion of the valve assembly 11 of the present invention, prior to assembling. As is best shown in Fig. 2, a pinion is indicated generally at 12. The pinion 12 is a generally cylindrical member including a gear portion 42 and a body portion 44. The gear portion 42 has helical gear teeth 36 formed on an outer surface of the gear portion 42 for meshing with the rack teeth 32 of the rack 16 as was described above. The body portion 44 of the pinion 12 has a generally cylindrical portion 46 and a frustoconical portion 48. The cylindrical portion 46 of the body 44 fits within and is secured with the gear portion 42 by welding, friction fitting, pinning, or keying the components together. Any other suitable method of connecting the cylindrical portion 46 and the gear portion 42 so that there is no rotation therebetween can also be used. Although the gear portion 42 and the body portion 44 are described herein as being two separate pieces, it can be appreciated that the pinion 12 can be formed as a single piece member, or having more than two pieces. The frustoconical portion 48 of the body portion 44 preferably is formed having a radially enlarged section 47 relative to the cylindrical portion 46 of the pinion 12. The frustoconical portion 48 of the body portion 44 also includes a bore 50. The bore 50 can extend any distance into the body portion 44. However, it is preferred that the bore 50 extend into the body portion 44 only partway into the pinion 12. It is further preferred that the bore 50 does not extend past the frustoconical portion 48 of the body portion 44. An inner end 52 of the bore 50 can be chamfered for receiving the correspondingly shaped torsion bar 20 as will be described below. It should be appreciated that although the bore 50 and torsion bar 20 are shown to be chamfered, as is known in the art for manufacturing these components, the components can be formed having any suitable form and structure for the purposes described herein.

[00027] As also shown in Fig. 2, a portion of a torsion bar is indicated generally at 20. The torsion bar 20 is formed from a suitable steel material that allows the torsion bar 20 to act as a torsion spring. The use of the torsion bar 20 as a torsion spring is known in the art. It is preferred that the portion of the torsion bar 20 that is designed to be received within the bore 50 is knurled or serrated (as designated by reference number 20A), to increase the "locking" or frictional engagement between the torsion bar 20 and the bore 50 during assembly. However, it is preferred that the torsion bar 20 is not knurled along its entire length for structural reasons. As can be seen a diameter D of the torsion bar 20 is less than the length of the torsion bar 20, and the diameter D of the torsion bar 20 is about the same as a diameter d of the bore of the pinion 12. It can be appreciated that the diameter D of the torsion bar 20, being described as having about the same size can mean that the diameter D of the torsion bar 20 is less than, equal to, or greater than the diameter, d, of the bore 50. In the preferred embodiment, the torsion bar 20 has a diameter D that is greater than or equal to the diameter d of the bore 50. To form this portion of the valve assembly 11, the torsion bar 20 is inserted into the bore 50 of the body portion 44 of the pinion 12 and retained with the pinion 12. In the preferred embodiment, the torsion bar 20 is driven at a high speed into the bore 50 of the pinion 12 as will be described in greater detail below. The high speed, pressure, and friction forces will function to secure the pinion 12 and the torsion bar 20 together as is shown in Fig. 3. In addition, one of the torsion bar 20 and pinion 12 can be held stationary while the other is rotated as the torsion bar 20 is driven into the bore 50 of the pinion 12. As can also be seen in Figs. 2 and 3, a driven end 54 of the torsion bar 20 is chamfered so as to be received within the chamfered inner end 52 of the bore 50 formed in the pinion 12. However, both the inner end 52 of the bore 50 and the driven end 54 of the torsion bar 50 can have any shape as is known in the art for manufacturing a "lead-in" for these components. When the torsion bar 20 is inserted into the bore 50 of the pinion 12, there may be a displacement of metal on the

pinion 12 or the input shaft 20, particularly in the embodiment where the diameter D of the torsion bar 20 is the same or greater than the diameter d of the bore 50.

[00028] Friction welding is a solid state welding process which produces coalescence of materials by the heat obtained from mechanically-induced sliding motion between rubbing surfaces. The parts to be joined are held together under pressure. This process usually involves the rotating of one part against another to generate frictional heat at the junction. When a suitable high temperature has been reached, the rotational motion is stopped. Additional pressure is then applied to the parts and coalescence between the parts occurs. There are two variations of a typical friction welding process. In one process one part is held stationary and the other part is rotated by a motor which maintains an essentially constant rotational speed. The two parts are brought in contact under pressure for a specified period of time with a specific pressure. Rotating power is disengaged from the rotating piece and the pressure is increased. When the rotating piece stops the weld is completed. This process can be accurately controlled when speed, pressure, and time are closely regulated.

[00029] Another variation of friction welding is called inertia welding. With inertia welding, a flywheel is revolved by a motor until a preset speed is reached. The flywheel, in turn, rotates one of the pieces to be welded. The motor is disengaged from the flywheel and the other part to be welded is brought in contact under pressure with the rotating piece. During the predetermined time during which the rotational speed of the part is reduced the flywheel is brought to an immediate stop and additional pressure is provided to complete the weld. Both methods utilize frictional heat and produce welds of similar quality. Among the advantages of friction welding is the ability to produce high quality welds in a short cycle time. No filler metal is typically required and flux is not used. However, a solder material can be used to facilitate the welding process if so desired. The process is capable of welding most of the common metals. It can also be used to join many combinations of dissimilar metals.

[00030] In a spin welding process, frictional heat is generated by holding one component still, while rotating the other at high speed and with controlled pressure. After a melt layer is formed, the rotation is halted and the material resolidifies. Three variables affect the spin weld process: speed of rotation, duration of rotation, and pressure applied to the joint. Each of the variables depends on the material and the diameter of the joint. In most cases, the actual spin time should be approximately 0.5 seconds, with an overall weld time of 2 seconds. Alternatively, the torsion bar 20 can be joined with the pinion 12 using a cold welding, explosion welding, ultrasonic welding, or any other solid state welding process. An advantage of using a solid state welding process is that there is no need or a limited need for brazing or flux materials. However, it can be appreciated that such materials can be used if so desired.

[00031] In the preferred embodiment, a high velocity insertion method is used to join the torsion bar 20 and the pinion 12 together. Using the high velocity insertion method, the pinion 12 is preferably secured in place relative to the torsion bar 20 as the torsion bar 20 is inserted into the bore 50. Any suitable mechanism can be used to hold the pinion 12 stationary during the process. As was stated above, the diameter D of the torsion bar 20 is about the same as the diameter d of the bore 50 of the pinion 12. It can be appreciated that the diameter D of the torsion bar 20 can be less than, equal to, or greater than the diameter d of the bore 50. In the preferred embodiment, the torsion bar 20 has a diameter D that is greater than or equal to the diameter d of the bore 50. The torsion bar 20 is moved at a high velocity into the bore 50 of the pinion 12 in a manner that is similar to that of a nail in a nail gun. The high velocity insertion method secures the torsion bar 20 within the bore 50 using a press fit. The process time of the high velocity insertion method is anticipated to be less than that required using the friction weld method described above. Additionally, it is possible that some of the metal of the torsion bar 20 and the pinion 12 could melt during the high velocity insertion method thereby creating a weld, which would further secure the components together. In addition, the end of the torsion bar 20 could be formed having a locking

taper such that the tapered end of the torsion bar 20 further secures the torsion bar 20 within the bore 50 of the pinion 12.

[00032] In an alternate embodiment of the invention, the end 54 of the torsion bar 20 that is to be driven into the pinion 12 can be coated with a material that turns into a semi-liquid when subjected to the friction of the solid state welding process. The semi-liquid material will then return to a solid state when cooled further, thereby increasing the locking of the friction weld. Regardless of the process used to join the torsion bar 20 and the pinion 12, it is preferred that the torsion bar 20 be substantially prevented from rotation relative to the pinion 12 (other than torsional rotation due to the spring-like qualities of the torsion bar 20). It should be appreciated that the spring rate of the torsion bar 20 can be changed by changing the location of the attachment point in the pinion 12 thereby changing the effective working length of the torsion bar 20.

[00033] Typically, once the torsion bar 20 and the pinion 12 have been assembled, the remaining portions of the valve assembly 11 are assembled. Illustrated in Fig. 4, there is shown a portion of the torsion bar 20 and the input shaft 18. As described above, the valve sleeve 21 is positioned over the torsion bar 20 and fixed with the pinion 12 (not shown in Fig. 4). The pinion 12 and the valve sleeve 21 can be joined using any suitable mechanism such as welding, crimping, pinning and keying. Conventionally, the pinion 12 and the valve sleeve 21 are retained for joint rotational movement by a pin being inserted into a hole formed through a portion of both the pinion 12 and the valve sleeve 21. Once the pinion 12 and the valve sleeve 21 are joined, the input shaft 18 can be positioned about the torsion bar 20 and within the valve sleeve 21. As described above, the rotation of the input shaft 18 relative to the valve sleeve 21 creates a hydraulic fluid flow to assist the rack and pinion steering assembly 10.

[00034] The input shaft 18 is an elongated tubular member having a bore 56 formed therethrough. The bore 56 of the input shaft 18 preferably has a diameter that is substantially the same as the outer diameter D of the torsion bar 20. Therefore, when

the input shaft 18 is positioned over the torsion bar 20 so that the torsion bar 20 is received within the bore 56, the torsion bar 20 is in a close fit relationship with the bore 56 of the input shaft 18. The input shaft 18 has an upper end 58 (closer to the steering wheel) having a splined section 60, and preferably a pair of spaced apart splined sections 60, as shown. The splined sections 60 are designed to be connected with a second shaft portion or a steering column (not shown) so that rotation of the steering wheel translates to the valve assembly 11 and more particularly, to the input shaft 18. A lower end of the input shaft 18 is preferably in rotational engagement with the pinion 12. Therefore, the length of the input shaft 18 is sufficient to pass through the valve sleeve 21 and into engagement with the pinion 12. The pinion 12 and the input shaft 18 can be connected by a generally conventional drive tang arrangement wherein rotation of the input shaft 18 also drives the rotation of the pinion 12. However, the input shaft 18 can be connected with the pinion 12 by any suitable mechanism such as with a splined connection, or by a keying arrangement.

[00035] Within the upper end 58 of the input shaft 18, there is formed an elongated cavity 62. The elongated cavity 62 is defined by an end 64 of the input shaft 18 and an inner surface 65 of the input shaft 18 in an area defined within the splined sections 60 of the input shaft 18. It can be appreciated that the cavity 62 can have any dimensions. A portion of the elongated cavity 62 is occupied by the torsion bar 20 when the input shaft 18 is positioned over the torsion bar 20, as was described above. An annular space 66 is defined by the remaining area between the outer diameter of the torsion bar 20 and the inner surface 65 of the elongated cavity 62 of the input shaft 18. Preferably, the torsion bar 20 is positioned coaxially within the elongated cavity 62 so that an annular space 66 is substantially equal on all sides of an outer surface 69 of the torsion bar 20. Thus, the cavity 62 does not extend in the input shaft 18 into the area of the valve assembly or the valve core 23. The purpose of the annular space 66 will be described next.

[00036] During a steering maneuver, it is preferred that the torsion bar 20 and the input shaft 18 rotate together. Therefore, the input shaft 18 and the torsion bar 20 are preferably secured together in rotational engagement. To create the rotational engagement between the input shaft 18 and the torsion bar 20, the input shaft 18 and the torsion bar 20 are preferably locked together by the use of a locking material 68.

[00037] In the preferred embodiment, once the valve assembly 11 is balanced, as was described above, and the neutral position of the torsion bar 20 is determined, the torsion bar 20 and the input shaft 18 can be locked together. The input shaft 18 and the torsion bar 20 are preferably locked together by the insertion of the locking material 68 into the annular space 66. In the preferred embodiment, the locking material 68 is in the form of a semi-solid locking slug material that is a quick setting material that substantially fills the annular space 66 and seals the elongated cavity 62 and the upper end of the bore 56 of the input shaft 18. The locking material 68 can be a plastic, a high temperature/high strength wax, nylon, a polymer, an epoxy, gel, or a metal injection. The locking material 68 is inserted or disposed into the annular space 66 in a semi-solid state. When the locking material 68 solidifies, the locking material 68 will act to retain the input shaft 18 and the torsion bar 20 together. Since the annular space 66 does not extend into the valve assembly 11, the locking material will be restricted from entering the valve assembly 11 and interfering with the operation of the components of the valve assembly 11. Positioned between the spaced apart splined portions 60 on the upper end 58 of the input shaft 18 is at least one port 70 formed through the input shaft 18. The port 70 is in fluid communication with the elongated cavity 62. It can be appreciated that a plurality of ports 70 can be formed through the input shaft 18. It is preferred that the locking material 68 be supplied into the annular space 66 formed within the elongated cavity 62 through the port 70. It can be appreciated that the locking material 68 could be supplied through the upper portion 58 of the input shaft 18 or through another opening formed in the input shaft 18. It is anticipated that the locking material 68 will solidify and thereby block or seal

the port 70. Some of the locking material 68 may also protrude through the port 70. Therefore, there is no requirement that the port 70 be further sealed by another device. In addition, the locking material 68 that protrudes through the port 70 can also assist with locking the input shaft 18 and the torsion bar 20 together. Visual inspection of the port 70 can also allow for easy determination of whether the locking material 68 has been inserted into and filled the annular space 66 and whether the locking material 68 has solidified.

[00038] It can be appreciated that the portion of the torsion bar 20 that is positioned within the elongated cavity 62 can be knurled (e.g., similar to that shown in Fig. 2 by reference character 20A), serrated, or roughened to create a better locking surface for the locking material 68. It should be appreciated that the input shaft 18 and the torsion bar 20 can be locked or secured together using any suitable mechanism. There is typically a low force being transmitted between the components within the valve assembly 11. However, due to the number of cycles which the valve assembly 11 is required to perform in a vehicle operation, it can be appreciated that the mechanism used to lock or secure the torsion bar 20 and the input shaft 18 must be capable of withstanding such repeated use.

[00039] The term valve assembly 11 has been used herein to describe a combined torsion bar 20, pinion 12, and input shaft 18. The valve assembly 11 has also been described as including a valve sleeve 21 and a valve core 23. It should be appreciated that the methods described above for joining the torsion bar 20, the pinion 12, and the input shaft 18 are equally applicable to other vehicle steering systems. For example, the method can be used in a vehicle having electronic steering, indicated generally at 10' in Fig. 5. In a vehicle that uses electronically controlled steering, it can be appreciated that there is no hydraulic valve required to control hydraulic fluid flow through the tower assembly. Thus, there will also not be any hydraulic conduits, collars or openings required. Instead, the input torque would be monitored electronically using sensors, mechanical switches, magnetic detection devices or any

other device that can measure relative movement between an input shaft 18' and a torsion bar 20'. Therefore, a valve assembly 90 according to this embodiment of the invention can also include components that measure relative movement between the input shaft 18' and the torsion bar 20' as is known in the art. A power assisted steering system 100 is illustrated schematically in Fig. 5. An electronic control unit 92 is connected to the valve assembly 90 and power assisted steering system 100 to monitor and control the operation thereof. An exemplary optical torque sensing mechanism is shown and described in U.S. Patent 5,369,583 to Hazelden, the disclosure of which is incorporated herein by reference. It would be apparent to one skilled in the art to configure an electromagnetic torque sensing mechanism (not shown) to operate with the embodiments of the invention that pertain to the method of joining the torsion bar and input shaft, as well as that aspect of the invention that pertains to the method of joining the torsion bar and the pinion as described herein.

[00040] In accordance with the provisions of the patent statutes, the principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

CLAIMS

What is claimed is:

1. A method for forming a portion of a rack and pinion steering assembly comprising:
 - (a) providing an input shaft having a bore and an elongated cavity, the bore including a first inner surface defining a first inner diameter and the elongated cavity including a second inner surface defining a second inner diameter which is greater than the first inner diameter;
 - (b) providing a torsion bar, the torsion bar including an outer surface defining an outer diameter that is less than the second inner diameter of the elongated cavity of the input shaft;
 - (c) positioning the torsion bar within the bore and the elongated cavity thereby forming a gap between at least portions of the outer surface of the torsion bar and the inner surface of the elongated cavity; and
 - (d) inserting a material into the gap for securing the input shaft to the torsion bar.
2. The method defined in Claim 1 wherein the torsion bar outer diameter is less than the first inner diameter of the bore of the input shaft.
3. The method defined in Claim 1 wherein the torsion bar outer diameter is generally equal to the first inner diameter of the bore of the input shaft.
4. The method defined in Claim 1 further comprising the steps of providing a port formed through the input shaft extending to the gap and inserting the material through the port and into the gap.

5. The method defined in Claim 1 wherein the material is a semi-solid material.
6. The method defined in Claim 4 wherein the semi-solid material is selected from the group consisting of a plastic, a wax, a nylon, a polymer, an epoxy, a gel, and a metal.
7. The method defined in Claim 1 wherein the gap is isolated from a valve section positioned about the input shaft.
8. The method defined in Claim 1 further comprising the step of balancing the input shaft and torsion bar, wherein the input shaft and torsion bar are balanced before inserting the locking material into the annular space.
9. The method defined in Claim 1 further comprising the step of providing a plurality of ports formed through the input shaft, the ports being in fluid communication with the gap.
10. The method defined in Claim 1 wherein at least a portion of the outer surface of the torsion bar is knurled.
11. The method defined in Claim 1 wherein the rack and pinion steering assembly is configured to operate with an electronically controlled power assisted steering system.

12. A method for forming a portion of a rack and pinion steering assembly comprising:

- (a) providing a torsion bar including an outer surface defining an outer diameter;
- (b) providing a pinion having a bore formed therein;
- (c) inserting a portion of the torsion bar into the bore of the pinion; and
- (c) securing the torsion bar to the pinion.

13. The method defined in Claim 12 wherein the torsion bar is inserted into the bore using a high velocity insertion method to thereby secure the torsion bar to the pinion.

14. The method defined in Claim 12 wherein the torsion bar includes an outer surface defining an outer diameter and the bore includes an inner surface defining an inner diameter which is generally equal to the outer diameter of the torsion bar.

15. The method defined in Claim 12 the bore includes an inner surface defining an inner diameter and the torsion bar includes an outer surface defining an outer diameter and which is generally larger than the inner diameter of the bore.

16. A method for forming a valve assembly for a rack and pinion steering apparatus comprising:

providing a pinion having a bore formed therein;

providing a torsion bar including an outer surface defining an outer diameter that is less than the second inner diameter of the elongated cavity of the input shaft;

providing a valve sleeve;

providing an input shaft having a bore and an elongated cavity, the bore including a first inner surface defining a first inner diameter and the elongated cavity including a second inner surface defining a second inner diameter which is greater than the first inner diameter;

forcing a portion of the torsion bar into the bore of the pinion to secure the torsion bar to the pinion;

positioning the valve sleeve over the torsion bar and pinion;

securing the valve sleeve to the pinion;

positioning a portion of the torsion bar within the bore of the input shaft wherein a first end of the torsion bar is positioned coaxially within the elongated cavity of the input shaft; and

inserting a material into the elongated cavity to secure the torsion bar and the input shaft together.

17. The method defined in Claim 16 further comprising the step of balancing the valve assembly, wherein the valve assembly is balanced before inserting the locking material into the elongated cavity.

18. The method defined in Claim 16 wherein an annular space is defined within the elongated cavity of the input shaft between the torsion bar and an inner surface of the elongated cavity; and

wherein the locking material is inserted into the annular space.

19. The method defined in Claim 18 further comprising the step of providing a port formed through the input shaft, the port being in fluid communication with the annular space for inserting the locking material through the port into the annular space.

20. The method defined in Claim 16 wherein the locking material is one of plastic, wax, nylon, a polymer, epoxy, gel, and metal.

21. The method defined in Claim 16 wherein the outer diameter of the torsion bar is about the same as the diameter of the bore.

22. A portion of a valve assembly for a rack and pinion steering assembly comprising:

an input shaft having a bore and an elongated cavity, the bore including a first inner surface defining a first inner diameter and the elongated cavity including a second inner surface defining a second inner diameter which is greater than the first inner diameter;

a torsion bar including an outer surface that defines an outer diameter that is less than the second inner diameter of the elongated cavity of the input shaft; and

a locking material;

wherein the torsion bar is located within the bore and the elongated cavity thereby forming a gap between at least portions of the outer surface of the torsion bar and the inner surface of the elongated cavity, and the locking material is positioned within the gap to secure the input shaft to the torsion bar.

23. The assembly defined in Claim 22 wherein the torsion bar outer diameter is less than the first inner diameter of the bore of the input shaft.

24. The assembly defined in Claim 22 wherein the torsion bar outer diameter is generally equal to the first inner diameter of the bore of the input shaft.

25. The assembly defined in Claim 22 further comprising a port formed through the input shaft extending to the gap, wherein the locking material can be inserted into the gap through the port.

26. The assembly defined in Claim 25 wherein the locking material is selected from the group consisting of a plastic, a wax, a nylon, a polymer, an epoxy, a gel, and a metal.

27. A portion of a rack and pinion steering assembly comprising:
a torsion bar including an outer surface defining an outer diameter;
a pinion having a bore formed therein;
wherein a portion of the torsion bar is positioned in the bore of the pinion and secured thereto.

28. The assembly defined in Claim 27 wherein the torsion bar includes an outer surface defining an outer diameter and the bore includes an inner surface defining an inner diameter which is generally equal to the outer diameter of the torsion bar.

29. The assembly defined in Claim 27 wherein the bore includes an inner surface defining an inner diameter and the torsion bar includes an outer surface defining an outer diameter and which is generally larger than the inner diameter of the bore.

30. A valve assembly for a rack and pinion steering apparatus comprising:

- a pinion having a bore formed therein;
- a torsion bar including an outer surface defining an outer diameter that is less than the second inner diameter of the elongated cavity of the input shaft;
- a valve sleeve; and
- an input shaft having a bore and an elongated cavity, the bore including a first inner surface defining a first inner diameter and the elongated cavity including a second inner surface defining a second inner diameter which is greater than the first inner diameter;

wherein a portion of the torsion bar is forced into the bore of the pinion to secure the torsion bar to the pinion;

- the valve sleeve is positioned over the torsion bar and pinion;
- the valve sleeve is secured to the pinion;
- a portion of the torsion bar is positioned within the bore of the input shaft such that a first end of the torsion bar is positioned coaxially within the elongated cavity of the input shaft; and
- a material is inserted into the elongated cavity to secure the torsion bar and the input shaft together to form the valve assembly.

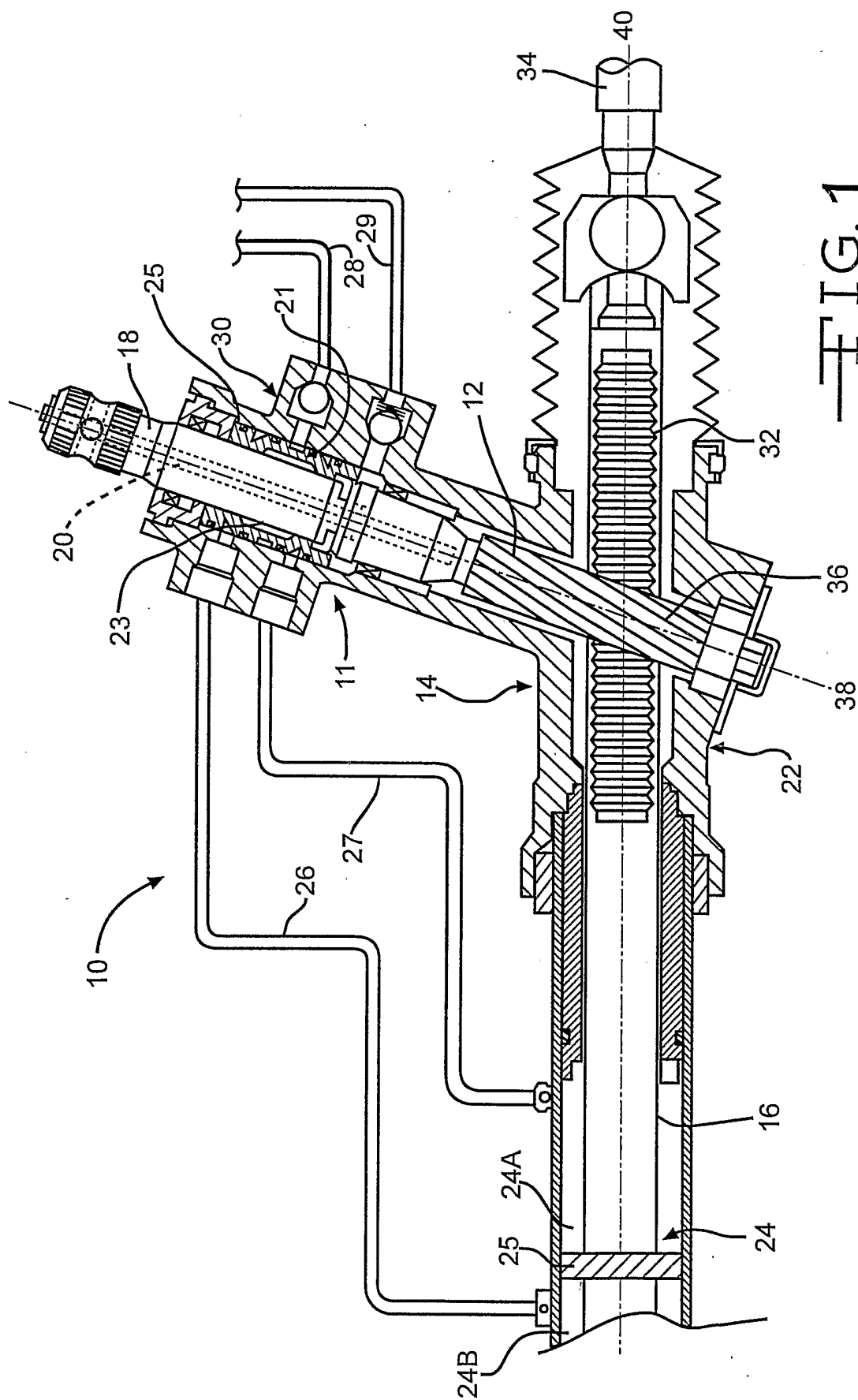


FIG. 1

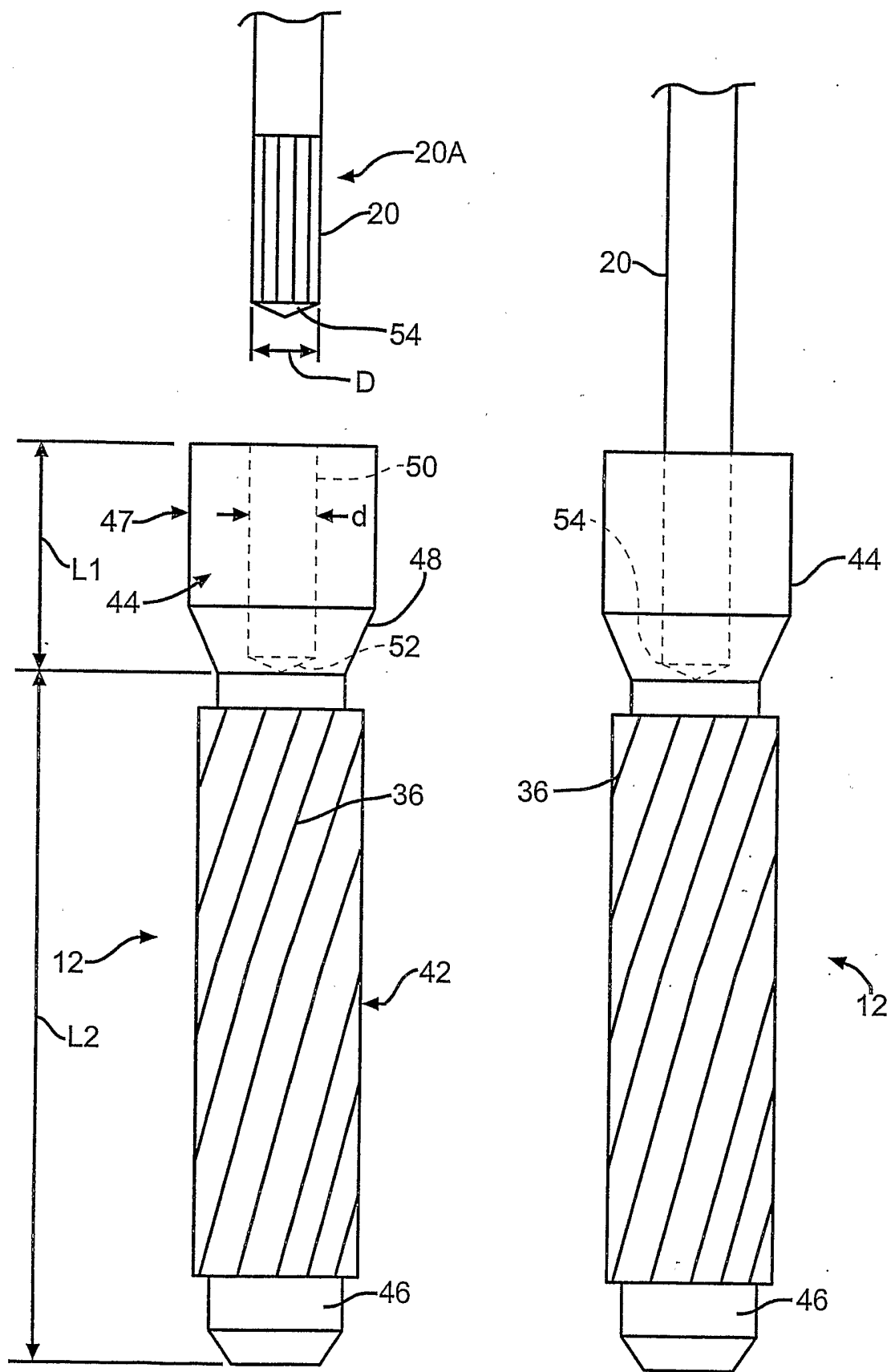


FIG. 2

FIG. 3

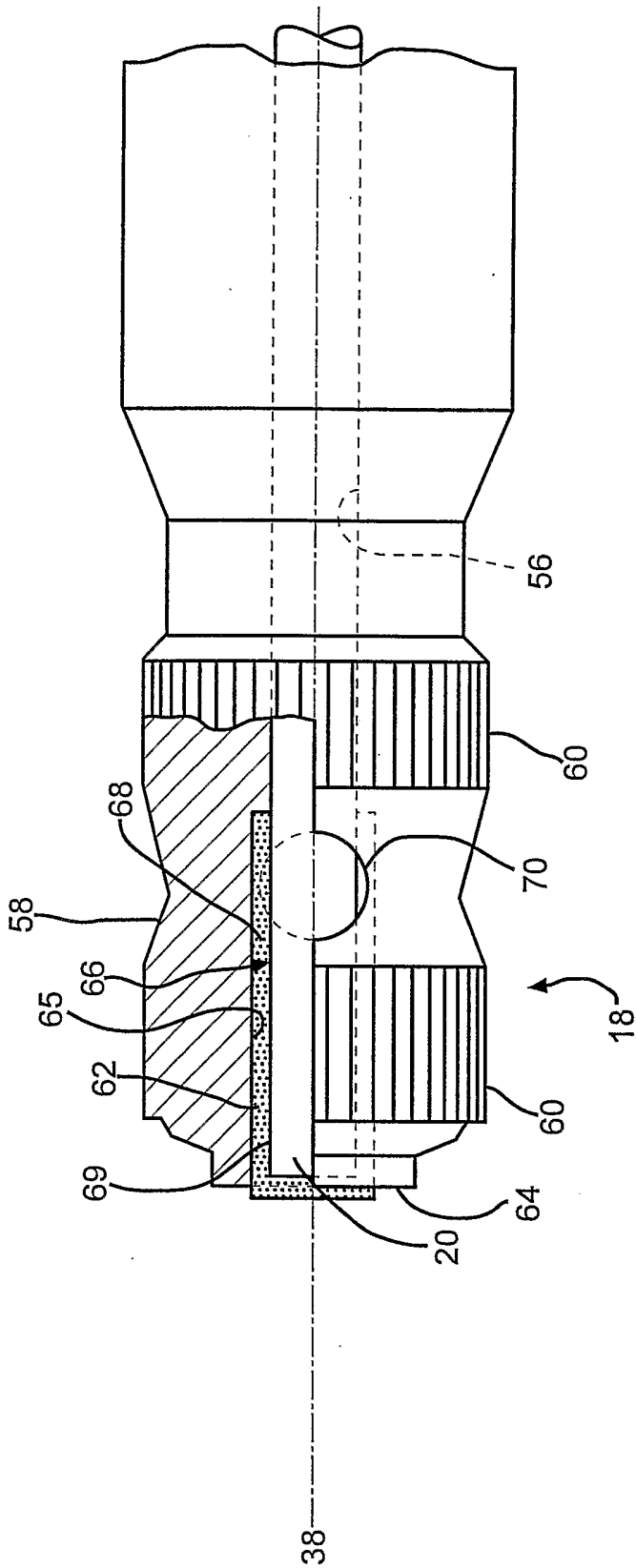


FIG. 4

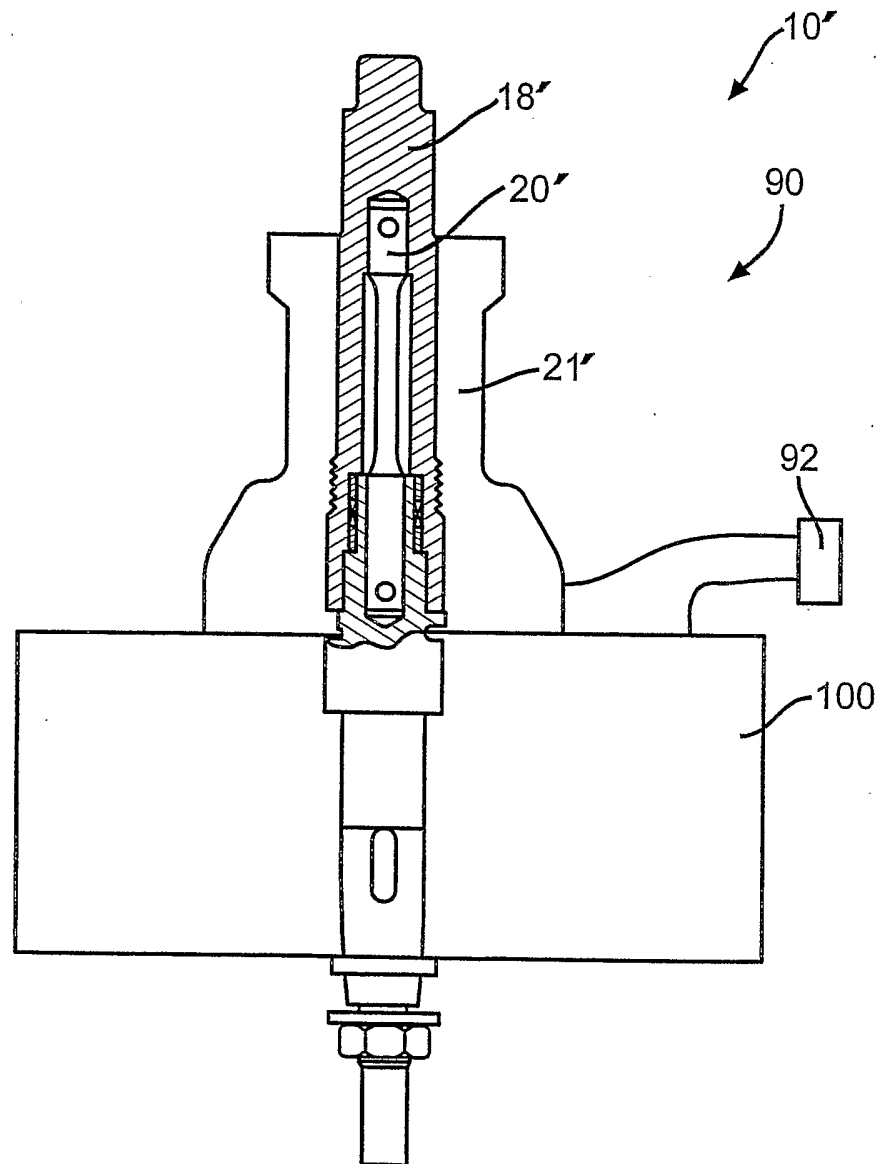


FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/017011

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B62D5/083

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)
IPC 7 B62D

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 4 214 642 A (DAUVERGNE, JEAN L R) 29 July 1980 (1980-07-29) the whole document	1-7, 10-16, 18-30
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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- *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
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Date of the actual completion of the international search

17 August 2005

Date of mailing of the international search report

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Van der Veen, F

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/017011

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