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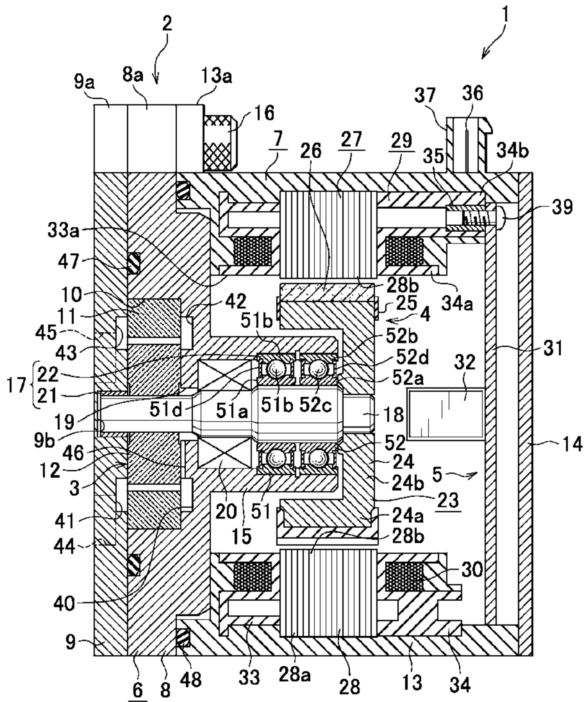
(54) Electric pump unit

(57) An electric pump unit including a pump body (6) formed of a pump housing (8) and a pump plate (9) provided in front of the pump housing. A motor housing (7) is fixed to a rear end of the pump housing (8), and accommodates a pump driving electric motor (4). A bearing device (17) that supports a motor shaft (18) includes a first bearing (21) that is arranged in a closed-end hole (9b) formed in a rear face of the pump plate (9) and supporting a front end portion of the motor shaft (18), and a second bearing (22) that is arranged radially inward of a cylindrical bearing support portion formed in the pump housing (8) and extending inside the motor housing (7) and that supports a middle portion of the motor shaft (18). A pump rotor (12) is arranged between the first bearing (21) and the second bearing (22).

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to an electric pump unit that is used as a hydraulic pump that supplies hydraulic pressure to, for example, a transmission (speed change gear) of an automobile.

2. Description of Related Art

[0002] Hydraulic pressure is supplied to a transmission of an automobile by a hydraulic pump. In an automobile in which so-called idle stop (idling stop) is performed, that is, an engine is stopped, when the automobile is stopped in view of , for example, energy saving, an electric hydraulic pump is used in order to ensure supply of hydraulic pressure to the transmission even during idle stop.

[0003] An electric hydraulic pump for a transmission of an automobile is mounted in a limited space in a vehicle body. Therefore, the electric hydraulic pump is required to be more compact, and also required to be lighter in weight and lower in cost. To fulfill such requirements, there is suggested an electric pump unit in which a pump, an electric motor for driving the pump, and a controller for the electric motor are assembled together in a common unit housing (refer to, for example, Japanese Patent Application Publication No. 2010-116914 (JP 2010-116914 A)).

[0004] In such a conventional electric pump unit, a motor housing is coupled to a rear side portion of a pump body that constitutes a pump, and an electric motor and a controller are accommodated in a sealed motor chamber formed inside the motor housing. The electric motor is arranged at the front side (the pump body side) inside the motor chamber, and a substrate of the controller is fixed to a rear end face of the electric motor. Further, a plurality of electrical parts (electrical components and electronic components), such as capacitors and FETs, that constitute the controller are mounted on the substrate.

[0005] The electric motor includes a motor rotor and a motor stator. The motor rotor is fixed to a free end portion at the rear side of a pump drive motor shaft that is supported by a bearing device. The motor stator is fixed to the motor housing. A pump chamber is formed inside the pump body. The pump body has a cylindrical bearing support portion that extends into the motor housing, and the bearing device for the motor shaft is provided inside the bearing support portion. The front portion of the motor shaft enters the pump chamber, and a pump rotor of the pump is fixed to a front-side free end portion of the motor shaft. When the pump is an internal gear pump, an inner gear that is an inner pump rotor is fixed to the front end portion of the motor shaft.

[0006] The bearing device includes two single-row deep groove ball bearings that are arranged side-by-side in the axial direction. An oil seal that seals a clearance between the pump chamber and the bearing device is provided in the bearing support portion of the pump body.

[0007] In the electric pump unit, two rolling bearings of the bearing device are arranged adjacent to each other in order to reduce the size of the electric pump unit. Thus, the motor shaft is supported in a cantilever manner, that is, one end of the motor shaft, on the motor rotor side, is supported, and the other end of the motor shaft, on the pump rotor side, is a free end. In addition, in order to reduce cost, each of the two rolling bearings is formed of a single-row deep groove ball bearing. Furthermore, in order to reduce assembly cost, the ball bearings are fitted to the bearing support portion and the motor shaft by clearance fit.

[0008] When the pump is an internal gear pump, an oil suction port and an oil discharge port are formed at symmetrical positions of the pump housing, which correspond to a portion at which the inner gear and an outer gear, which is an outer pump rotor, are in mesh with each other.

[0009] In the above-described conventional electric pump unit, during an operation of the pump, although the pressure in the oil suction port of the pump chamber is low, the pressure in the oil discharge port becomes high. Therefore, radial force acts on the front end portion (pump housing-side end portion) of the motor shaft to which the inner gear is fixed and which is supported in a cantilever manner. As described above, the single-row deep groove ball bearings, that is, the two rolling bearings of the bearing device arranged side-by-side, are fitted by clearance fit. Therefore, the bearing support stiffness is low, and the motor shaft is inclined. Due to the inclination of the motor shaft, the inner gear is inclined and rotates while being in contact with the motor housing. Therefore, noise may occur, and abrasion may occur in the motor rotor and the motor housing.

SUMMARY OF THE INVENTION

[0010] It is an object of the invention to provide an electric pump unit in which the bearing support stiffness of a bearing device is increased to reduce inclination of a motor shaft and a motor rotor.

[0011] An aspect of the invention relates to an electric pump unit that includes: a pump body of a pump that sucks in and discharges fluid, wherein the pump body includes a pump housing and a pump plate, the pump housing forms a pump chamber that accommodates a pump rotor, and the pump plate is provided at one end of the pump housing; a motor housing that is fixed to the other end of the pump housing and that accommodates a pump driving electric motor; and the electric motor that includes a motor shaft that is supported by a bearing device and that rotates the pump rotor, a motor rotor that is fixed to a motor housing-side end portion of the motor shaft, and a motor stator that is fixed to the motor housing.

The bearing device includes a first bearing that is arranged in a closed-end hole formed in the pump plate and that supports a pump housing-side end portion of the motor shaft, and a second bearing that is arranged radially inward of a cylindrical bearing support portion formed in the pump housing and extending inside the motor housing, and that supports a middle portion of the motor shaft. The pump rotor is arranged between the first bearing and the second bearing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a longitudinal sectional view of main portions of an electric pump unit according to a first embodiment of the invention;

FIG. 2 is a longitudinal sectional view of main portions of an electric pump unit according to a second embodiment of the invention;

FIG. 3 is a longitudinal sectional view of main portions of an electric pump unit according to a third embodiment of the invention;

FIG. 4 is a view schematically showing an example of a manner of assembling the electric pump unit in the first embodiment of the invention;

FIG. 5A and FIG. 5B are views for illustrating the operation and effect of the assembling manner shown in FIG. 4; and

FIG. 6A and FIG. 6B are views for illustrating a problem of an assembling manner that is compared with the assembling manner shown in FIG. 4.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] Hereinafter, an electric pump unit for a transmission of an automobile according to embodiments of the invention will be described with reference to the accompanying drawings. FIG. 1 is a longitudinal sectional view of main portions of an electric pump unit according to a first embodiment of the invention. In the following description, the left side in FIG. 1 is defined as the front side, and the right side in FIG. 1 is defined as the rear side.

[0014] An electric pump unit 1 is formed by assembling a pump 3 that sucks in and discharges oil, a pump driving electric motor 4, and a controller 5 for the electric motor 4 together in a unit housing 2. In this example, the pump 3 is an internal gear pump, and the motor 4 is a sensorless-controlled DC brushless motor that has three-phase coils.

[0015] The unit housing 2 is formed of a pump body 6 of the pump 3 and a motor housing 7 that accommodates the electric motor 4 and the controller 5.

[0016] The pump body 6 is formed of a pump housing 8 and a pump plate 9 arranged in front of the pump housing 8. The pump housing 8 is formed in a thick plate member that extends in a direction perpendicular to the front-rear direction, and has a pump chamber 10 at its center portion. The pump chamber 10 is open at its front side. The pump plate 9 is fixed to the front face of the pump housing 8 via an O-ring 47 to close the front side of the pump chamber 10. An outer gear 11 that serves as an outer pump rotor is rotatably accommodated in the pump chamber 10. An inner gear 12 that serves as an inner pump rotor and that is in mesh with the outer gear 11 is arranged radially inward of the outer gear 11. The pump housing 8 and the pump plate 9 are made of, for example, an aluminum alloy.

[0017] The motor housing 7 is formed of a cylindrical motor case 13 made of synthetic resin and a disc-shaped lid 14. The lid 14 is fixed to the rear end of the motor case 13. The front end of the motor case 13 is fixed to the rear face of the pump housing 8 via an O-ring 48. The pump plate 9, the pump housing 8, and the motor case 13 are fixed, at coupling portions 9a, 8a, 13a, to each other with bolts 16. The coupling portions 9a, 8a, 13a are integrally formed with the pump plate 9, the pump housing 8, and the motor case 13 so as to protrude radially outward from the outer peripheries of the pump plate 9, pump housing 8, and motor case 13, respectively. The rear end opening of the motor case 13 is closed by the lid 14.

[0018] The electric motor 4 has a motor shaft 18 that serves as a pump drive shaft that extends in the front-rear direction. The motor shaft 18 is supported by a bearing device 17. The bearing device 17 is formed of a first bearing 21 and a second bearing 22. The first bearing 21 supports the front end portion (pump housing-side end portion) of the motor shaft 18. The second bearing 22 supports the motor shaft 18 at its middle portion in the front-rear direction.

[0019] The second bearing 22 is formed of two deep groove ball bearings 51, 52 that are arranged adjacent to each other in the front-rear direction. Each of the deep groove ball bearings 51, 52 is a sealed type bearing with grease lubrication. The deep groove ball bearing 51 includes an inner ring 51a, an outer ring 51b, a plurality of balls (rolling elements) 51c, and a pair of seals 51d. The deep groove ball bearing 52 includes an inner ring 52a, an outer ring 52b, a plurality of balls (rolling elements) 52c, and a pair of seals 52d.

[0020] The motor shaft 18 is formed in a stepped shape. The front portion of the motor shaft 18 extends through the center portion of the pump housing 8 and enters the pump chamber 10, and the front end portion of the motor shaft 18 is fitted into a closed-end hole 9b formed in the rear face of the pump plate 9.

[0021] The first bearing 21 is formed of a cylindrical bushing (cylindrical metal member), and is fixed to the closed-end hole 9b formed in the rear face of the pump plate 9 by interference fit. The front end portion of the motor shaft 18 is fitted into the first bearing 21 by clearance fit. Thus, the inner periphery of the first bearing 21 (bushing) and the outer periphery of the front end portion of the motor shaft 18 are slidable with respect to each other. Thus, the first bearing 21 constitutes a plain bearing.

[0022] A cylindrical bearing support portion 15 that is smaller in diameter than the motor case 13 is integrally formed at the center of the rear end face of the pump housing 8, and extends into the motor case 13.

[0023] The inner rings 51a, 52a of the deep groove ball bearings 51, 52 are fitted to the motor shaft 18 by interference fit, and the outer rings 51b, 52b of the deep groove ball bearings 51, 52 are fitted to the bearing support portion 15 by clearance fit.

[0024] An oil seal 20 is arranged between the second bearing 22 and the inner gear 12. The oil seal 20 seals the clearance between the bearing support portion 15 and the motor shaft 18.

[0025] The inner gear 12 is fitted to the motor shaft 18 at a portion close to the front end portion of the motor shaft 18 by interference fit so as to be in contact with the rear face of the pump plate 9. Through the interference fit (press-fitting), the inner gear 12 is fixed to the motor shaft 18 with its axial and radial movements restricted.

[0026] A motor rotor 23 that constitutes the motor 4 is fixed to the rear end portion (motor housing-side end portion) of the motor shaft 18, which protrudes rearward from the bearing support portion 15. In the motor rotor 23, a permanent magnet support member 25 made of synthetic resin is fixedly provided at the outer peripheral portion of a cylindrical rotor body 24 and segmented permanent magnets 26 are supported at multiple portions of the support member 25, which are equiangularly aligned in the circumferential direction.

[0027] A motor stator 27 that constitutes the motor 4 is fixed to the inner periphery of the motor case 13, which faces the motor rotor 23. In the stator 27, an insulator (synthetic resin insulator) 29 is assembled to a stator core 28 made of laminated steel sheets and coils 30 are wound around portions of the insulator 29. In this example, the stator 27 is molded integrally with the inner peripheral portion of the motor case 13.

[0028] The rotor body 24 is formed of a cylindrical portion 24a and a flange 24b. The rotor body 24 has a U-shape in lateral cross section. The cylindrical portion 24a faces the motor stator 27. The flange 24b extends radially outward from the rear end of the motor shaft 18, and is integrated with the cylindrical portion 24a.

[0029] A substrate 31 of the controller 5 is fixed to the rear end of the insulator 29, and a component 32 that constitutes the controller 5 is mounted on the substrate 31. FIG. 1 shows only one component 32 that is mounted on the front face of the substrate 31. However, a component is arranged at a predetermined position of at least one of the front face and rear face of the substrate 31. The component 32 shown in FIG. 1 is, for example, an electrolytic capacitor.

[0030] In the stator core 28, pole portions (teeth) 28b that protrude radially inward are integrally formed at multiple portions of the inner periphery of an annular portion 28, which are aligned equiangularly in the circumferential direction. The distal end portion of each pole portion 28b extends on both sides in the circumferential direction, and the inner peripheries of the pole portions 28b form a single cylindrical face.

[0031] The insulator 29 is formed of a pair of front and rear halves 33, 34. Each of the halves 33, 34 is molded from synthetic resin, such as polyphenylene sulfide (PPS) resin. The halves 33, 34 are assembled to the stator core 28 from the front side and the rear side so as to cover the surface of the stator core 28, other than the outer periphery of the annular portion 28a and the inner peripheries of the pole portions 28b. The halves 33, 34 respectively have coil fitting portions 33a, 34a that cover portions of the stator core 28, other than the inner peripheries of the pole portions 28b. At each of the pole portions 28b of the stator core 28, the coil 30 is wound around a portion covered with the coil fitting portions 33a, 34a of the halves 33, 34. Substrate mounting protruding portions 34b that extend rearward are integrally formed at multiple portions of the rear half 34, which are located radially outward of the coil fitting portion 34a and which are equiangularly aligned in the circumferential direction. A metal internal thread member 35 is embedded inside the rear end portion of each protruding portion 34b. An internal thread is formed on the inner periphery of each metal internal thread member 35.

[0032] The motor case 13 is integrated with the stator 27 by molding synthetic resin, such as polyamide 66 (PA66), at the outer peripheral portion of the stator 27 using a die. The surface of the stator 27, other than the inner peripheries of the pole portions 28b of the stator core 28, the inner peripheries of the coil fitting portions 33a, 34a of the insulator 29 and the rear end faces of the protruding portions 34b, are covered with the motor case 13. A connector 37 provided with a plurality of pins 36 is integrally formed with the outer periphery of the motor case 13.

[0033] The lid 14 is made of synthetic resin, and is fixed to the rear end of the motor case 13 by an appropriate method, such as thermal welding.

[0034] The substrate 31 of the controller 5 is fixed to the insulator 29 by screws 39 that are screwed to the internal thread members 35 at the protruding portions 34b of the insulator 29. Although not shown in the drawing, a plurality of bus bars is assembled to a molded body formed of the insulator 29 and the motor case 13, and the coils 30 of the stator 27 are electrically connected to each other and electrically connected to the substrate 31 via the bus bars. The pins 36 of the connector 37 are also electrically connected to the substrate 31.

[0035] Oil suction ports 40, 41 are respectively formed in the walls of the pump housing 8 and the pump plate 9, which face each other and which correspond to a meshing portion (in this example, a lower-side meshing portion) at which the inner gear 12 and the outer gear 11 of the pump 3 are in mesh with each other. Oil discharge ports 42, 43 are respectively formed in the walls of the pump housing 8 and the pump plate 9, which face each other and which correspond to a meshing portion (in this example, upper-side meshing portion) at which the inner gear 12 and outer gear 11 of the pump 3 are in mesh with each other. The pump plate 9 has an oil suction hole 44 and an oil discharge hole 45. The oil suction hole 44 is in communication with the oil suction port 41. The oil discharge hole 45 is in communication with the oil discharge port 43. The wall of the pump housing 8, which faces the pump chamber 10, has an oil release groove 46. The oil release groove 46 provides communication between a hole 19, through which the motor shaft 18 is passed, and the oil suction port 40.

[0036] When the pump 3 is driven by the electric motor 4 and the inner gear 12 and the outer gear 11 rotate, the pressure in the oil suction ports 40, 41 is low, and the pressure in the oil discharge ports 42, 43 is high. Therefore, the inner gear 12 receives radial (in this example, downward) force.

[0037] In the above embodiment, the middle portion of the motor shaft 18 in the front-rear direction is supported by the second bearing 22, and the front end portion of the motor shaft 18 is supported by the first bearing 21. Therefore, the bearing support stiffness improves, and, even when radial force due to hydraulic pressure acts on the inner gear 12, inclination of the motor shaft 18 is prevented. As a result, it is possible to suppress slanting of the pump 3, and to reduce noise and abrasion.

[0038] In addition, because the first bearing 21 is a plain bearing such as a bushing, it is possible to install the first bearing 21 in a small space, and to easily ensure sites for the oil suction port 41, the oil discharge port 43, the oil suction hole 44, the oil discharge hole 45, and the like, in the pump plate 9.

[0039] In addition, because the inner gear 12 is fitted to the motor shaft 18 by interference fit, axial movement of the motor shaft 18 is restricted to suppress a backlash. Therefore, the outer rings 51b, 52b of the deep groove ball bearings 51, 52 may be fitted to the bearing support portion 15 by clearance fit, and no circlip needs to be provided between the outer rings 51b, 52b. Therefore, it is easy to fit the bearings 51, 52, and efficiency of assembly improves. However, in order to further improve the bearing support stiffness, the outer rings 51b, 52b of the deep groove ball bearings 51, 52 may be fitted to the bearing support portion 15 by interference fit.

[0040] FIG. 2 is a longitudinal sectional view of main portions of an electric pump unit according to a second embodiment of the invention. The second embodiment differs from the first embodiment in the configuration of a rotary portion including a bearing device. Hereinafter, the same components as those in the first embodiment will be denoted by the same reference numerals as those in the first embodiment, and the description thereof is omitted.

[0041] In the present embodiment, a bearing device 61 that supports a motor shaft 60 of the electric motor 4 is formed of a first bearing 63 and a second bearing 64. The second bearing 64 supports the motor shaft 60 at its middle portion in the front-rear direction. The first bearing 63 supports the front end portion of the motor shaft 60. The first bearing 63 is a bushing as in the case of the first embodiment. The second bearing 64 is a single deep groove ball bearing.

[0042] The motor shaft 60 is formed in a circular columnar shape, unlike the first embodiment in which the motor shaft is formed in a stepped shape. In addition, the axial length of the motor shaft 60 is shorter than that in the first embodiment because the second bearing 64 is formed of the single deep groove ball bearing.

[0043] A bearing support portion 62 that is integrally formed with the pump housing 8 is formed of a thick portion 62a and a thin portion 62b that is located behind the thick portion 62a. The thick portion 62a is smaller in inside diameter and larger in outside diameter than the thin portion 62b. An inward flange 62c is provided on the inner periphery at the boundary between the thick portion 62a and the thin portion 62b.

[0044] The second bearing 64 is arranged on the inner periphery of the thick portion 62a, and an oil seal 65 is arranged on the inner periphery of the thin portion 62b. The oil seal 65 seals the clearance between the bearing support portion 62 and the motor shaft 60. The interference of the oil seal 65 is slightly smaller than that in the first embodiment.

[0045] The second bearing 64 is arranged such that an inner gear 12 (pump rotor) is interposed between the second bearing 64 and the first bearing 63. The second bearing 64 is an open-type deep groove ball bearing that has an inner ring 64a, an outer ring 64b, and a plurality of balls (rolling elements) 64c. The inner ring 64a is fitted to the middle portion of the motor shaft 60 by interference fit, and the outer ring 64b is fitted to the thick portion 62a of the bearing support portion 62 by interference fit.

[0046] A front end-side portion of the motor shaft 60 is coupled to the inner gear 12 by a dowel pin 66. The dowel pin 66 is a coupling member for coupling the motor shaft 60 to the inner gear 12 such that the motor shaft 60 and the inner gear 12 rotate together with each other and do not move relative to each other in the axial direction. Thus, the inner gear 12 is fixed to the motor shaft 60 with its axial and radial movements restricted. The coupling member may be a pin, such as a spiral pin, or a key, instead of the dowel pin 66.

[0047] A motor rotor 67 is fixed to the rear end portion (motor housing-side end portion) of the motor shaft 60. The motor stator 27 is provided at the same position as that in the first embodiment. A rotor body 68 of the motor rotor 67 is formed of a cylindrical portion 68a and a flange 68b. The cylindrical portion 68a faces the motor stator 27. The flange 68b extends radially outward from the rear end of the motor shaft 61, and is integrated with the cylindrical portion 68a. Because the axial length of the motor shaft 60 is shorter than that in the first embodiment, the rotor body 68 is formed in a shape (the lateral sectional shape is an I-shape) in which the flange 68b is fixed to substantially the center of the cylindrical portion 68a in the axial direction.

[0048] In this second embodiment as well as in the first embodiment, the middle portion of the motor shaft 60 in the front-rear direction is supported by the second bearing 64, and the front end portion of the motor shaft 60 is supported by the first bearing 63. Thus, the bearing support stiffness improves, and, even when radial force due to hydraulic pressure acts on the inner gear 12, inclination of the motor shaft 60 is prevented. Thus, it is possible to suppress slanting of the pump 3, and to reduce noise and abrasion. In addition, because the inner ring 64a and the outer ring 64b of the second bearing 64 are fitted by interference fit, the bearing support stiffness is further improved.

[0049] In addition, because the motor shaft 60 and the inner gear 12 are coupled to each other by the dowel pin 66, axial movement of the motor shaft 60 is restricted to suppress a backlash.

[0050] In addition, because the flange 68b of the rotor body 68 is fixed to substantially the center portion of the cylindrical portion 68a in the axial direction, the rotor body 68 is well-balanced in comparison with the rotor body 24 in the first embodiment in which the flange 24b is fixed to the rear end portion of the cylindrical portion 24a. As a result, it is possible to prevent runout of the motor rotor 67.

[0051] The rear portion of the bearing support portion 62 is the thin portion 62b in order to avoid contact with the motor rotor 67. Further, the front portion that does not contact the motor rotor 67 is the thick portion 62a. Because the outer ring 64b of the second bearing 64 is fitted to the thick portion 62a by interference fit, it is possible to sufficiently provide interference between the bearing support portion 62 and the outer ring 64b. Thus, no additional slipping prevention measures (such as prevention of axial movement using a circlip) need to be taken. In addition, because stiffness increases owing to the inward flange 62c, deformation of the bearing support portion 62 at the time of press-fitting of the oil seal 65 is prevented, and interference is stable.

[0052] FIG. 3 is a longitudinal sectional view of main portions of an electric pump unit according to a third embodiment of the invention. The third embodiment differs from the second embodiment in the configuration of a bearing device including an oil seal. Hereinafter, the same components as those in the first and second embodiments will be denoted by the same reference numerals as those in the first and second embodiments, and the description thereof is omitted.

[0053] A bearing device 71 according to the present embodiment is formed of a first bearing 73 and a second bearing 74, as in the case of the first and second embodiments.

[0054] A bearing support portion 72 that is integrally formed with the pump housing 8 is formed of a thick portion 72a and a thin portion 72b located behind the thick portion 72a. The thick portion 72a is equal in inside diameter to the thin portion 72b and is larger in outside diameter than the thin portion 72b. An inward flange 72c is provided at the front end portion of the thick portion 72a. An oil seal 75 is arranged radially inward of the thick portion 72a, and the second bearing 74 is arranged radially inward of the thin portion 72b.

[0055] The first bearing 73 is a bushing, as in the cases of the first and second embodiments. The second bearing 74 is a sealed type deep groove ball bearing with grease lubrication, and includes an inner ring 74a, an outer ring 74b, a plurality of balls (rolling elements) 74c, and a pair of seals 74d.

[0056] The second bearing 74 is arranged such that an inner gear 12 (pump rotor) and the oil seal 75 are interposed between the second bearing 74 and the first bearing 73. The second bearing 74 is arranged such that the inner ring 74a is fitted to the middle portion of the motor shaft 60 by interference fit and the outer ring 74b is fitted to the thin portion 72b of the bearing support portion 72 by interference fit.

[0057] In the third embodiment, the positional relationship between the oil seal 75 and the second bearing 74 is inverted from that in the second embodiment. Thus, the second bearing 74 is arranged near the rear end portion of the motor shaft 60 and, as compared with the second embodiment, the distance between the first bearing 73 and the second bearing 74 is increased. Thus, the bearing support stiffness is further improved.

[0058] As in the case of the second embodiment, the lateral sectional shape of the motor rotor 67 is an I-shape. This shape is effective in preventing runout of the motor rotor 67.

[0059] In the first embodiment described above, the outer rings 51b, 52b of the two deep groove ball bearings 51, 52 that constitute the second bearing 22 are fitted to the bearing support portion 15 of the pump housing 8 by clearance fit. In addition, the front end portion of the motor shaft 18 is fitted into the first bearing 21 by clearance fit. An example of the assembling manner in this case is shown in FIG. 4.

[0060] In FIG. 4, the assembly is performed such that an axis 18a of the motor shaft 18 is closer to the oil discharge port side than an axis 21a of the first bearing 21 is. Note that, although the clearance formed by the clearance fit is actually approximately several tens of μm (e.g. approximately 20 μm on the first bearing 21 side, and approximately 10 μm on the second bearing 22 side), the clearance is schematically illustrated in an exaggerated manner in FIG. 4.

[0061] The assembly is usually performed such that the axis 21a of the first bearing 21 coincides with the axis 18a of the motor shaft 18 and therefore the front end portion of the motor shaft 18 is located at the middle between the oil suction port 41 and the oil discharge port 43, as shown in FIG. 6A. In contrast to this, according to the present embodiment, as shown in FIG. 4 and FIG. 5A, the assembly is performed such that the front end portion of the motor shaft 18 is located closer to the oil discharge port side than to the oil suction port side. In this way, the hydraulic pressure on the oil suction port side becomes lower than the hydraulic pressure on the oil discharge port side when the hydraulic pressure is applied, and the clearance on the oil suction port side is larger than the clearance on the oil discharge port side before the hydraulic pressure is applied.

[0062] The pump 3 of the electric pump unit 1 according to the invention is a pump that operates when a vehicle is placed in idling stop and an engine is stopped. Therefore, when the pump 3 is operating, the other parts are at a standstill. Accordingly, if the acoustic pressure of the noise generated from the pump 3 is high, a driver may feel uncomfortable. Therefore, it is necessary to reduce the level of noise that is generated from the pump 3.

[0063] If the assembly is performed as shown in FIG. 6A, the axis 18a of the motor shaft 18 and the axis 21a of the first bearing 21 coincide with each other when the hydraulic pressure is not applied. When the hydraulic pressure is applied, the hydraulic pressure on the oil discharge port side becomes high, and therefore, the front end portion of the motor shaft 18 is pushed toward the oil suction port side as shown in FIG. 6B. Thus, the motor shaft 18 may slide over the first bearing 21 on the oil suction port side. The sliding noise may increase the low-frequency (281 to 2245 Hz) acoustic pressure.

[0064] In contrast to this, if the assembly is performed as shown in FIG. 5A, the axis 18a of the motor shaft 18 is already located closer to the oil discharge port side than to the oil suction port side when the hydraulic pressure is not applied. When the hydraulic pressure is applied, the hydraulic pressure becomes high on the oil discharge port side. Therefore, as shown in FIG. 5B, the front end portion of the motor shaft 18 is pushed toward the oil suction port side. At this time, the clearance on the oil discharge port side, which has been small, is increased. If the clearance is equal to or larger than 10 μm, an oil film is formed between the motor shaft 18 and the first bearing 21 and therefore the motor shaft 18 rotates without being in friction contact with the first bearing 21. In this way, it is possible to reduce the low frequency (281 to 2245 Hz) acoustic pressure due to the sliding noise between the motor shaft 18 and the first bearing 21.

[0065] In order to obtain a clearance as shown in FIG. 5A, the motor shaft 18 may be brought closer to the oil discharge port side by applying a load of, for example, 5 to 30N to the motor shaft 18.

[0066] By performing the assembly as described above, it is possible to reduce the low-frequency acoustic pressure, and it is possible to suppress fluctuation of the acoustic pressure by reducing the variations of the assembled position. Further, it is possible to improve the durability by reducing occurrence of the friction contact between the first bearing 21 and the motor shaft 18.

[0067] In the above embodiments, the first bearings 21, 63, 73 of the bearing devices 17, 61, 71 are bushings that serve as plain bearings, and the second bearings 22, 64, 74 are formed of deep groove ball bearings. However, the invention is not limited to this configuration. The first bearing may be a rolling bearing, and the second bearing may be a rolling bearing other than a deep groove ball bearing. When the first bearing is a rolling bearing, the first bearing is desirably formed of a needle roller bearing. The needle roller bearing, for example, includes a cylindrical outer ring, a plurality of needle rollers arranged along the bore surface of the outer ring and a cage that retains the plurality of needle rollers. The outer ring is fixedly press-fitted to the peripheral wall of the closed-end hole 9b. If the first bearing is formed of a needle roller bearing instead of a ball bearing, it is possible to easily ensure sufficient assembling efficiency and sufficient space for ports even when the rolling bearing is used.

[0068] The overall configuration of the electric pump unit and the configuration of the portions of the electric pump unit are not limited to those in the above-described embodiments, and may be modified as needed.

[0069] In addition, the invention may also be applied to an electric pump unit other than an electric pump unit for a transmission.

[0070] With the electric pump unit according to the invention, it is possible to increase the bearing support stiffness of the bearing device to thereby reduce inclination of the motor shaft and inclination of the pump rotor.

Claims

1. An electric pump unit, comprising:

a pump body of a pump that sucks in and discharges fluid, wherein the pump body includes a pump housing and a pump plate, the pump housing forms a pump chamber that accommodates a pump rotor, and the pump plate is provided at one end of the pump housing;
a motor housing that is fixed to the other end of the pump housing and that accommodates a pump driving electric motor; and
the electric motor that includes a motor shaft that is supported by a bearing device and that rotates the pump rotor, a motor rotor that is fixed to a motor housing-side end portion of the motor shaft, and a motor stator that is fixed to the motor housing,
wherein the bearing device includes a first bearing that is arranged in a closed-end hole formed in the pump plate and that supports a pump housing-side end portion of the motor shaft, and a second bearing that is arranged radially inward of a cylindrical bearing support portion formed in the pump housing and extending inside the motor housing, and that supports a middle portion of the motor shaft, and
wherein the pump rotor is arranged between the

first bearing and the second bearing.

2. The electric pump unit according to claim 1, wherein the first bearing is a plain bearing.

3. The electric pump unit according to claim 1 or 2, wherein:

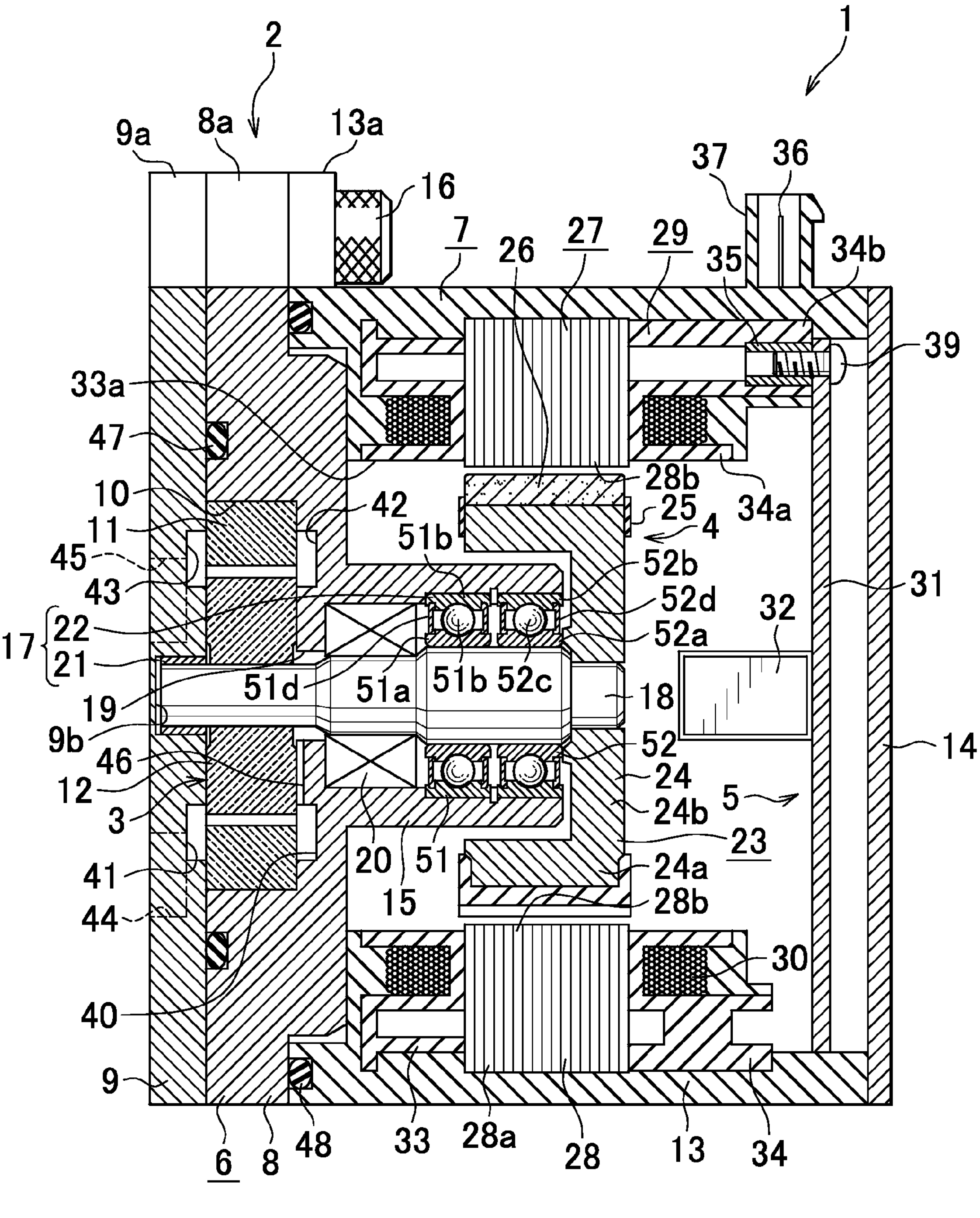
the pump rotor is formed of an outer gear and an inner gear;
the inner gear is fixed to the motor shaft with axial and radial movements of the inner gear restricted;
the second bearing is a rolling bearing that includes an inner ring, an outer ring and rolling elements; and
the inner ring is fitted to a middle portion of the motor shaft by interference fit.

4. The electric pump unit according to claim 3, wherein the outer ring of the second bearing is fitted to the bearing support portion by interference fit.

5. The electric pump unit according to claim 3, wherein:

the first bearing is formed of a cylindrical metal member;
the motor shaft is fitted to the first bearing by clearance fit;
the outer ring of the second bearing is fitted to the bearing support portion by clearance fit; and
the motor shaft is fitted to the first bearing such that an axis of the motor shaft is located closer to an oil discharge port side than an axis of the cylindrical metal member is.

FIG.1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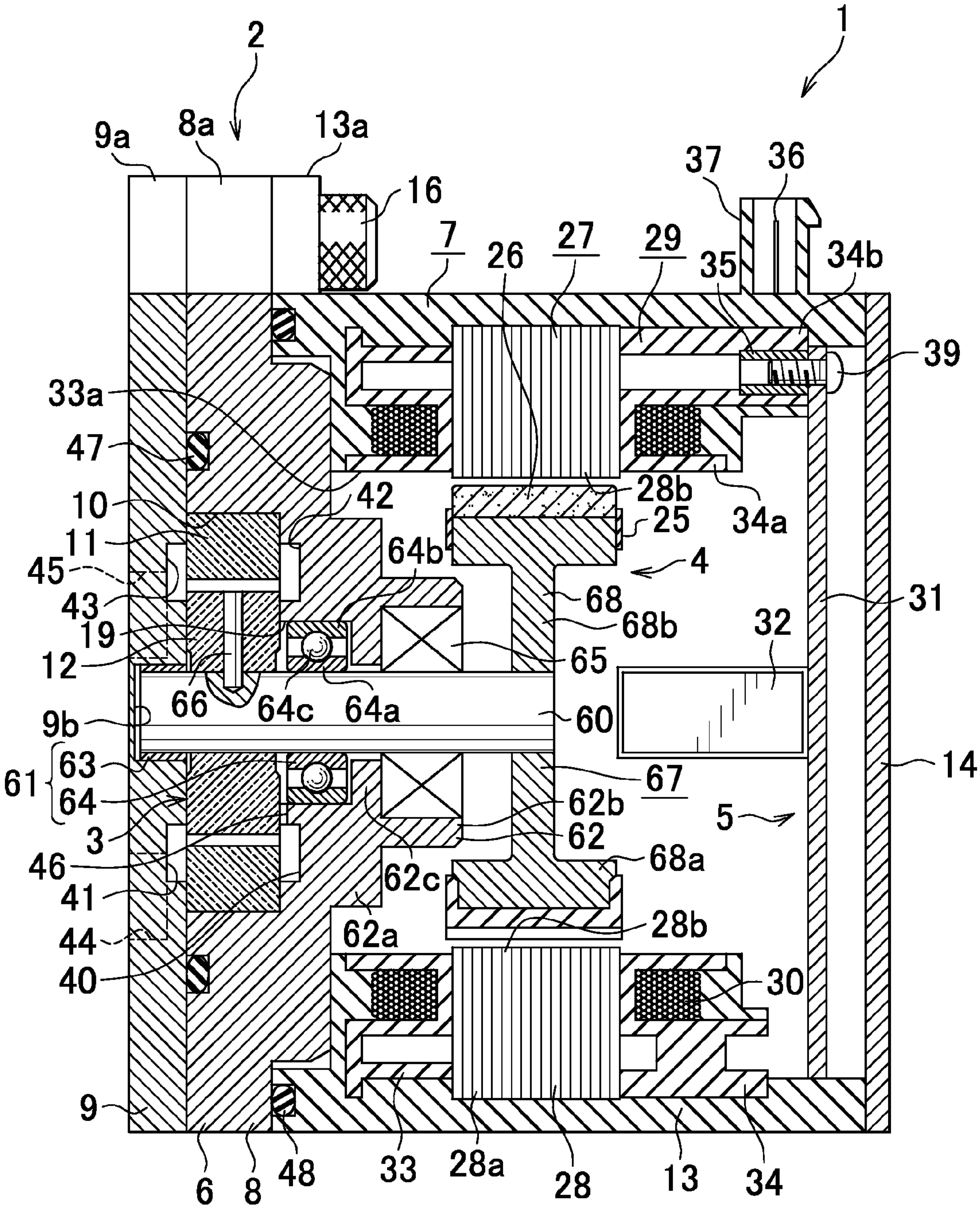
8a
13a
16
7
26
27
29
37
36
35
34b
39
33a
47
28b
34a
10
42
25
4
11
51b
45
43
52b
52d
32
31
17
22
21
52a
51d
51a
51b
52c
18
19
9b
52
14
46
24
12
5
24b
3
20
51
23
41
15
24a
44
28b
30
40
9
6
8
48
33
28a
28
13
34

FIG.2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26
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29
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34b
39
33a
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11
64b
4
45
43
68
31
19
68b
32
12
65
66
64c
64a
9b
60
61
63
67
14
64
62b
5
3
62
46
68a
41
62c
28b
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62a
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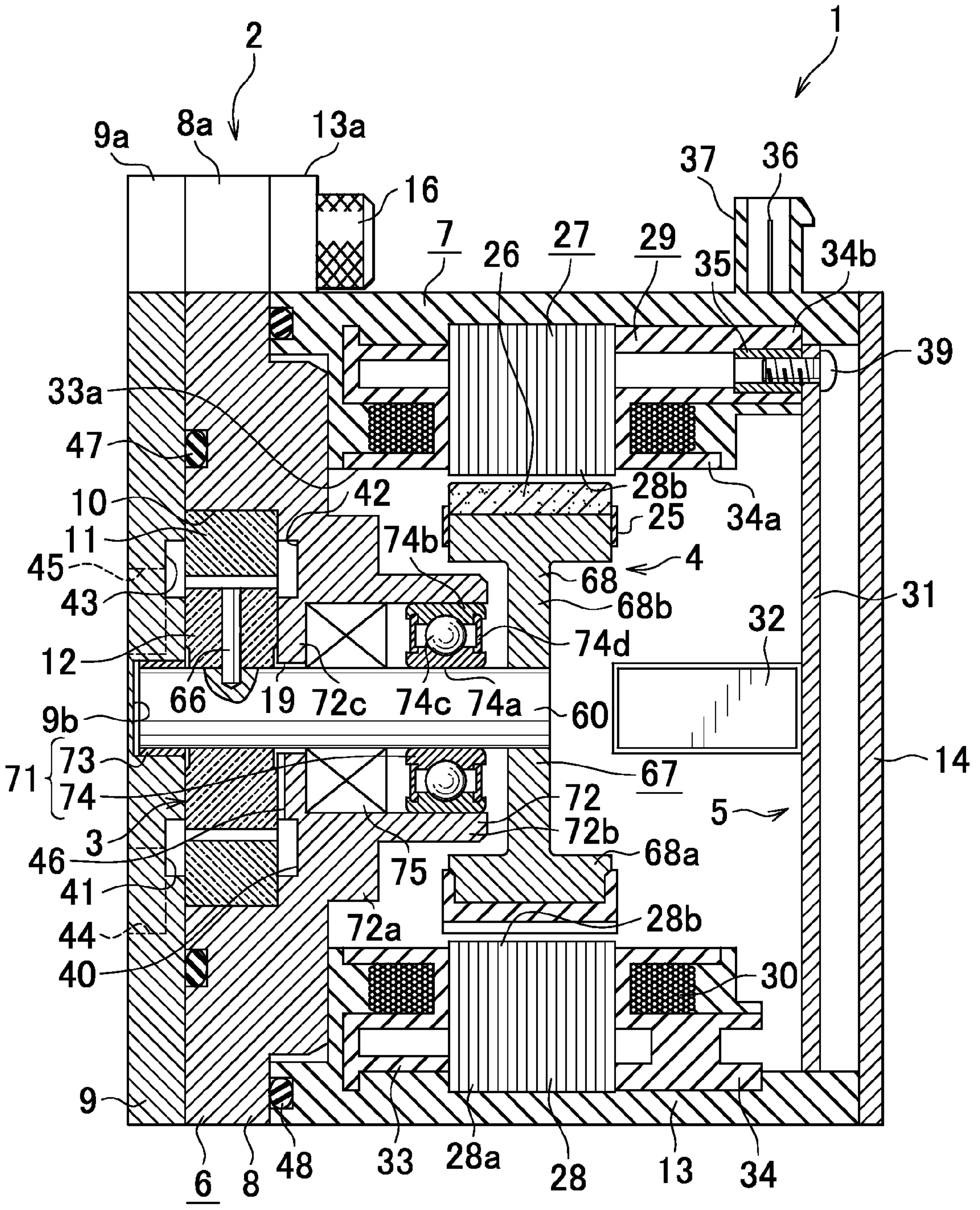
30
9
6
8
48
33
28a
28
13
34

FIG. 3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8a
13a
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34b
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33a
47
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43
12
66
19
72c
74c
74a
60
42
28b
25
74b
4
68
68b
74d
32
31
34a
9b
73
74
71
3
46
41
44
40
9
6
8
48
33
28a
28
13
34
67
72
72b
5
68a
75
72a
28b
30
14

FIG. 4

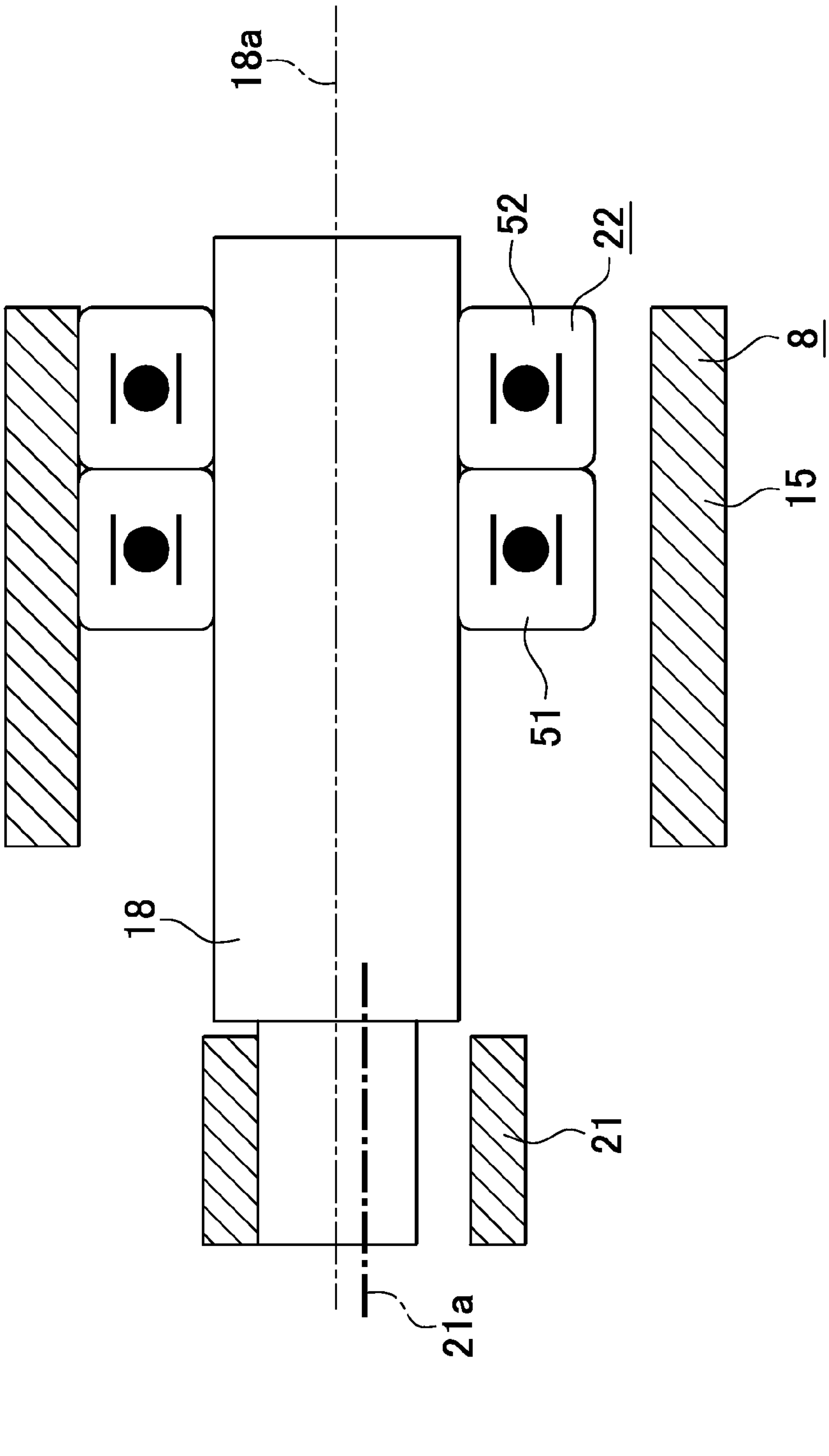


FIG. 5A

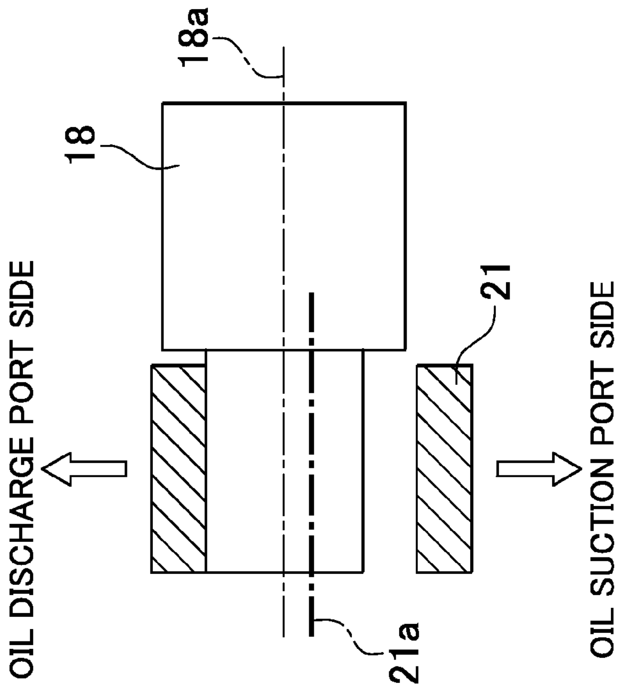

18a
18
21
21a
OIL DISCHARGE PORT SIDE
OIL SUCTION PORT SIDE

FIG. 5B

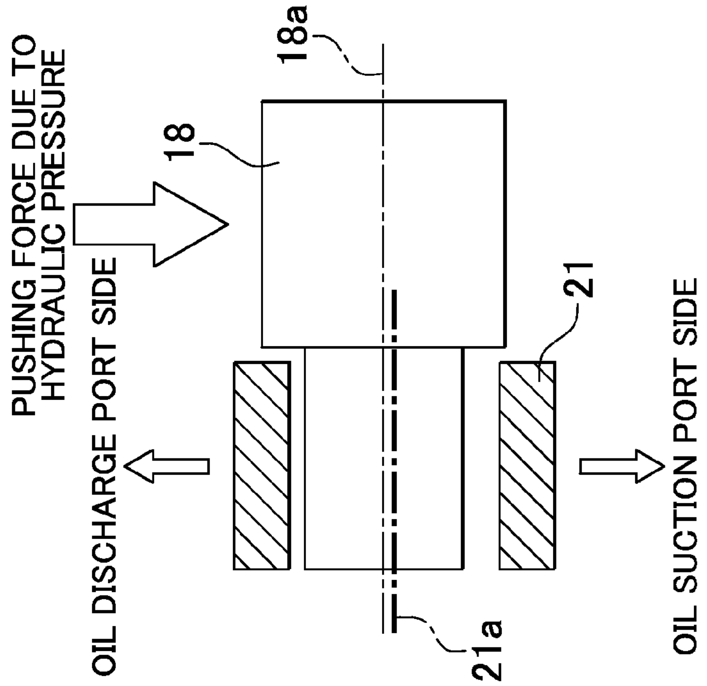

PUSHING FORCE DUE TO
HYDRAULIC PRESSURE
18a
18
21
21a
OIL DISCHARGE PORT SIDE
OIL SUCTION PORT SIDE

FIG. 6A

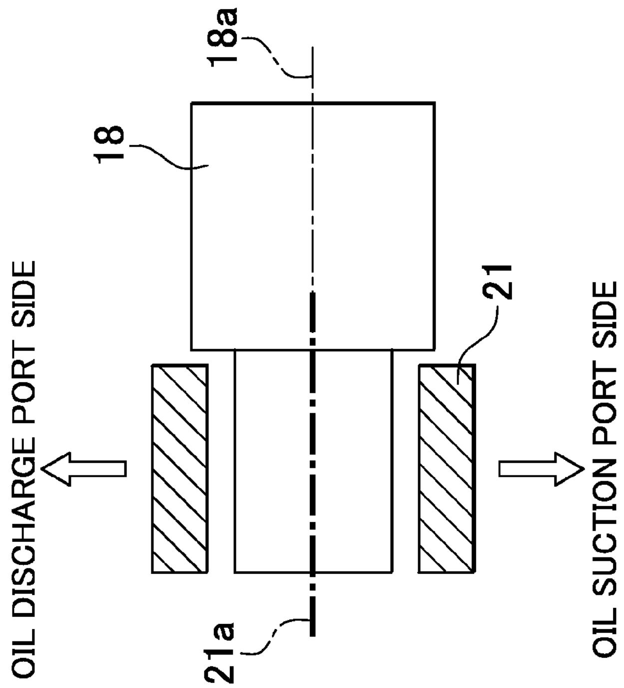
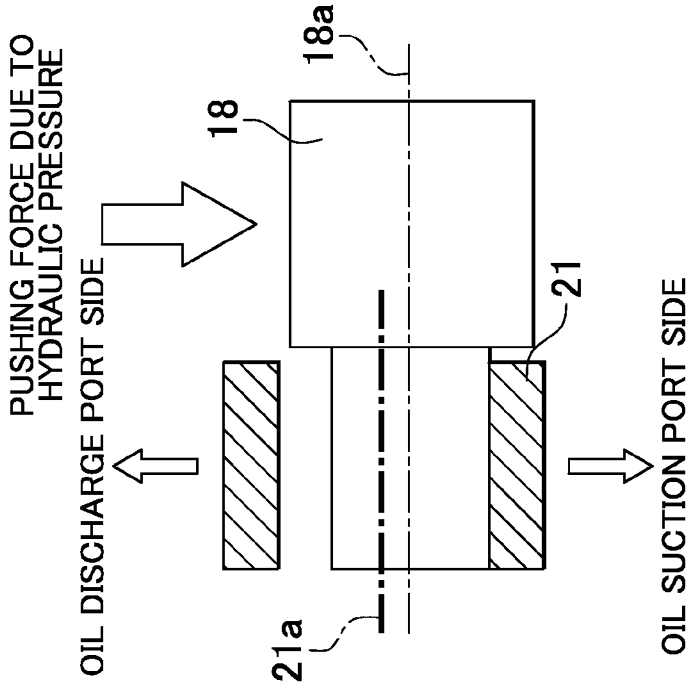

18a
18
21
OIL DISCHARGE PORT SIDE
OIL SUCTION PORT SIDE
21a

FIG. 6B


PUSHING FORCE DUE TO HYDRAULIC PRESSURE
18a
18
21
OIL DISCHARGE PORT SIDE
OIL SUCTION PORT SIDE
21a

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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