



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.02.2012 Bulletin 2012/06

(51) Int Cl.:
F01L 1/34 (2006.01) F16H 1/32 (2006.01)

(21) Application number: **10758520.0**

(86) International application number:
PCT/JP2010/055183

(22) Date of filing: **25.03.2010**

(87) International publication number:
WO 2010/113747 (07.10.2010 Gazette 2010/40)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

• **SAITO Takahide**
Iwata-shi
Shizuoka 438-0037 (JP)
• **ISODA Koji**
Iwata-shi
Shizuoka 438-0037 (JP)

(30) Priority: **03.04.2009 JP 2009091022**

(71) Applicant: **NTN Corporation**
Osaka-shi, Osaka 550-0003 (JP)

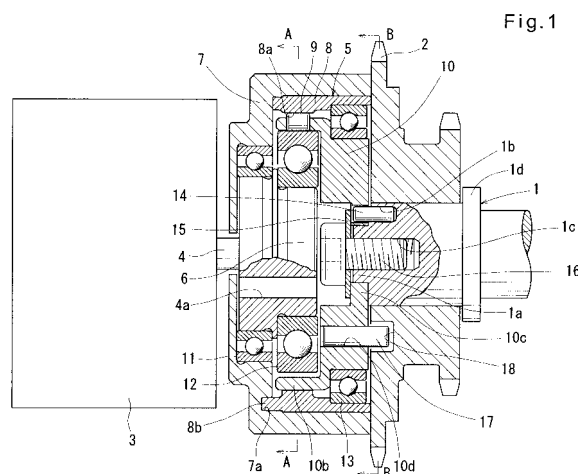
(74) Representative: **Grünecker, Kinkeldey, Stockmair & Schwanhäusser**
Anwaltssozietät
Leopoldstrasse 4
80802 München (DE)

(72) Inventors:
• **SATO Koji**
Iwata-shi
Shizuoka 438-0037 (JP)

(54) **VARIABLE VALVE TIMING DEVICE**

(57) A variable valve timing device is provided having a speed reduction mechanism that is simple in structure and which can keep the relative rotation between the camshaft and the sprocket within a predetermined angular range even if the speed reduction mechanism malfunctions. A camshaft (1) and a sprocket (2) are coaxially provided so as to be rotatable relative to each other. A speed reduction mechanism (5) is mounted in a housing (7) which is rotationally fixed to the sprocket (2). The speed reduction mechanism (5) includes an intermediate shaft (10) having a retainer portion (10b) retaining a plurality of rollers (9) disposed between the outer periphery of an eccentric shaft portion (6) of an output shaft (4) of an electric motor (3) and an internal gear (8) fixed in position in the housing (7). The intermediate shaft (10) has a stopper pin (17) provided on the intermediate shaft (10) engaged in an engaging recess (18) formed in the sprocket (2) so as to be movable within the range of the circumferential length of the recess (18). When the output shaft (4) of the electric motor (3) rotates, the rollers (9) are pressed against the teeth of the internal gear (8) by the eccentric shaft portion (6) and revolve around the output shaft (4). The revolution of the rollers (9) is transmitted to the camshaft (1) through the intermediate shaft (10), thus changing the angular position of the camshaft (1) relative to the sprocket. If the speed reduction mechanism (5) malfunctions, the stopper pin (17) engages the

engaging recess (18), thus restricting the relative rotation between the intermediate shaft (10) and the stopper pin (17) within a predetermined angular range.



Description**TECHNICAL FIELD**

[0001] This invention relates to a variable valve timing device which can change the timing of opening and closing intake valves or exhaust valves of an engine.

BACKGROUND ART

[0002] Intake valves, through which an air-fuel mixture is fed into an engine, and exhaust valves, through which exhaust gas is discharged, are opened and closed in synchronization with the engine stroke. A variable valve timing device is known which changes the timing of opening and closing of the valves, thereby improving fuel economy of the engine and reducing exhaust gas.

[0003] Fig. 12 shows a conventional variable valve timing device (such as disclosed in Patent document 1) comprising a camshaft 41 for driving engine valves, a sprocket 42 through which the engine revolution is transmitted to the camshaft 41 and which is arranged coaxial with the camshaft 41 so as to be rotatable relative to the camshaft 41, an electric motor 43 having an output shaft 44 coaxial with the camshaft 41, and a speed reduction mechanism 45 and the link mechanism 46 through which the rotation of the output shaft 44 of the motor 43 is transmitted to the camshaft 44, thereby changing the angular position of the camshaft 41 relative to the sprocket 42 by rotating the camshaft 41 and the sprocket 42 relative to each other, in order to change the timing of opening and closing of the engine valves.

[0004] The speed reduction mechanism 45 includes an internal gear 47 rotatably supported on an eccentric shaft portion 44a of the output shaft 44 of the electric motor 43 through a bearing, and having part of its teeth meshing with an external gear 49 provided on a housing 48 integral with the sprocket 42, so that when the output shaft 44 is rotated relative to the sprocket 42, the internal gear 47 rotates around the eccentric shaft portion 44a. The rotation of the internal gear 47 is transmitted to a guide plate 50, and the rotation of the guide plate 50 is transmitted to the cam plate 41a which is rotationally fixed to the camshaft 41a through the link mechanism 46, which comprises arms 46a and 46b, thereby rotating the camshaft 41 relative to the sprocket 42.

PRIOR ART DOCUMENT(S)**PATENT DOCUMENT(S)**

[0005] Patent document 1: JP Patent Publication 2008-57349A see Figs. 3 to 8

[0006] By rotating the camshaft 41 relative to the sprocket 42 and thus changing the angular position of the camshaft 41 relative to the crankshaft, it is possible to change the timing of opening and closing of the engine intake valves or exhaust valves.

SUMMARY OF THE INVENTION**OBJECT OF THE INVENTION**

[0007] With the electric variable valve timing device disclosed in Patent document 1, the rotation of the output shaft 44 of the electric motor 43 is transmitted to the camshaft 41 through the complicated structure comprising the speed reduction mechanism 45 and the link mechanism 46, which makes it difficult to reduce the size of the device. If the speed reduction mechanism 45 malfunctions, it may become impossible to keep the angular position between the camshaft 41 and the sprocket 42 within a predetermined angular range because there is no backup mechanism for transmitting the rotation of the output shaft 44 of the electric motor 43 to the camshaft 41.

[0008] An object of the present invention is to simplify the structure of the speed reduction mechanism and to keep the relative rotation between the camshaft and the sprocket within a predetermined angular range even if the speed reduction mechanism malfunctions.

MEANS TO ACHIEVE THE OBJECT

[0009] In order to achieve this object, the present invention provides a variable valve timing device comprising a camshaft for driving at least one of an intake valve and an exhaust valve of an engine, and a sprocket configured to be rotated by the engine to drive the camshaft, the camshaft and the sprocket being arranged coaxially with each other so as to be rotatable relative to each other, an electric motor having an output shaft, and a speed reduction mechanism through which the rotation of the output of the electric motor can be transmitted to the camshaft at a reduced rate, thereby changing the angular position of the camshaft relative to the sprocket, wherein the speed reduction mechanism comprises an eccentric shaft portion provided on the output shaft of the electric motor and having a circular cross-section, a housing fixed to the sprocket, an internal gear fixedly mounted in the housing and having teeth, a plurality of rollers disposed between the internal gear and an outer periphery of the eccentric shaft portion, and an intermediate shaft coaxial with the camshaft and including an annular retainer portion formed with circumferentially equidistantly spaced pockets in which the respective rollers are retained, wherein the number of the pockets of the retainer portion is smaller or larger by one than the number of the teeth of the internal gear, wherein each tooth of the internal gear has a profile that coincides with the locus of the radially outermost portion of each roller which is parallel to the locus of the center of the roller 9, when the output shaft of the electric motor rotates and the rollers revolve around the output shaft, whereby the revolution of the rollers is transmitted to the camshaft through the intermediate shaft, and wherein the variable valve timing device further includes restricting means for restricting the rotation of the camshaft relative to the

sprocket within a predetermined angular range.

[0010] With this arrangement, as the output shaft of the electric motor rotates, the rollers are pressed against the teeth of the internal gear by the outer periphery of the eccentric shaft portion, and revolve around the eccentric shaft portion. The revolution of the rollers is transmitted to the camshaft through the intermediate shaft, which has the integral retainer portion retaining the rollers. Thus, the speed reduction mechanism alone can both reduce the rotational speed of the output shaft of the electric motor and transmit the thus reduced rotation of the output shaft to the camshaft. This eliminates the necessity for a complicated structure comprising a speed reducing mechanism for reducing the rotational speed of the output shaft of the electric motor and a link mechanism for transmitting the thus reduced rotation of the output shaft to the camshaft, as was necessary in the conventional arrangements. The speed reduction mechanism of the present invention is thus simple in structure.

[0011] The restricting means restricts the angular position of the camshaft relative to the sprocket within a predetermined angle even if the speed reduction mechanism malfunctions.

[0012] The restricting means may comprise a protrusion provided on one of the intermediate shaft and the sprocket, and a circumferentially elongated engaging recess formed in the other of the intermediate shaft and the sprocket, the protrusion being engaged in the engaging recess such that the protrusion is movable within the range of the circumferential length of the engaging recess, whereby the relative rotation between the intermediate shaft and the sprocket is restricted within an angle formed between two lines connecting the center of the sprocket to the protrusion when the protrusion is at the respective extreme circumferential ends of the engaging recess.

[0013] With this arrangement, due to the engagement of the protrusion in the engaging recess, the relative rotation between the intermediate shaft and the sprocket is restricted within an angle formed between two lines connecting the center of the sprocket to the protrusion when the protrusion is at the respective extreme circumferential ends of the engaging recess. This makes it possible to keep the rotation of the camshaft relative to the sprocket within the above predetermined angle range.

[0014] Alternatively, the restricting means may comprise a protrusion provided on one of the sprocket and the camshaft, and a circumferentially elongated engaging recess formed in the other of the sprocket and the camshaft, the protrusion being engaged in the engaging recess such that the protrusion is movable within the range of the circumferential length of the engaging recess, whereby the relative rotation between the sprocket and the camshaft is restricted within an angle formed between two lines connecting the center of the sprocket to the protrusion when the protrusion is at the respective extreme circumferential ends of the engaging recess.

[0015] With this arrangement, due to the engagement

of the protrusion in the engaging recess, the relative rotation between the sprocket and the camshaft is restricted within an angle formed between two lines connecting the center of the sprocket to the protrusion when the protrusion is at the respective extreme circumferential ends of the engaging recess. This makes it possible to keep the relative rotation between the sprocket and the camshaft within the above predetermined angle range.

[0016] The camshaft may be formed with an oil passage through which engine oil can pass, and the sprocket may be formed with an oil path through which engine oil supplied from the oil passage can be supplied to the speed reduction mechanism.

[0017] Ordinarily, an engine has an oil sump from which engine oil is supplied to engine parts to lubricate the engine parts. The oil sump is connected to the oil passage of the camshaft, so that the parts of the speed reduction mechanism are lubricated with engine oil that is supplied through the oil passage and the oil path.

[0018] An oil reservoir for engine oil may be provided in the oil passage. The oil reservoir allows smooth and quickly supply of engine oil stored in the oil reservoir to the speed reduction mechanism especially when the engine is started or during hard acceleration of the engine, at which time it is usually difficult to supply enough oil to the speed reduction mechanism. Also, the oil reservoir reduces a sudden change in the amount of engine oil supplied to the speed reduction mechanism, thus stabilizing the amount of engine oil supplied.

[0019] An oil filter may be provided in the oil passage to remove foreign matter that enters the oil passage from outside, such as metal dust contained in engine oil circulating through the engine, thereby preventing deterioration in the lubricating ability.

[0020] In the arrangement in which the camshaft has the oil passage through which engine oil flows and the sprocket has the oil path through which engine oil from the oil passage is supplied to the speed reduction mechanism, the valve timing device may further comprise an intermediate support bearing comprising a slide bearing disposed around an outer periphery of the intermediate shaft and fixedly fitted in a cylindrical portion of the internal gear.

[0021] With this arrangement, since the interior of the speed reduction mechanism is lubricated by engine oil, it is possible to use as the intermediate support bearing a slide bearing, which is simpler in structure and less expensive than a rolling bearing, which is ordinarily used for this purpose, and which includes inner and outer races adapted to slide on each other through an oil film. This reduces the manufacturing cost of the speed reduction mechanism.

[0022] The variable valve timing device may further comprise an output support bearing comprising a slide bearing disposed around an outer periphery of the output shaft of the electric motor and fixedly fitted in a cylindrical portion of the housing. With this arrangement too, since the interior of the speed reduction mechanism is lubri-

cated by engine oil, it is possible to use as the intermediate support bearing a slide bearing, which is simpler in structure and less expensive than a rolling bearing, which is ordinarily used for this purpose, and which includes inner and outer races adapted to slide on each other through an oil film. This reduces the manufacturing cost of the speed reduction mechanism.

[0023] In the arrangement in which the camshaft has the oil passage through which engine oil flows and the sprocket has the oil path through which engine oil from the oil passage is supplied to the speed reduction mechanism, the intermediate shaft and the internal gear may be configured to be rotatable relative to each other with an outer periphery of the intermediate shaft in sliding contact with an inner periphery of a cylindrical portion of the internal gear.

[0024] With this arrangement, since an oil film of engine oil is present between the outer periphery of the intermediate shaft and the radially inner surface of the cylindrical portion of the internal gear, the intermediate shaft and the cylindrical portion of the internal gear can smoothly rotate relative to each other. This eliminates the necessity to provide a bearing between the intermediate shaft and the cylindrical portion of the internal gear, thus reducing the number of parts of the device.

[0025] In the arrangement in which the camshaft has the oil passage through which engine oil flows and the sprocket has the oil path through which engine oil from the oil passage is supplied to the speed reduction mechanism, the output shaft of the electric motor and the housing may be configured to be rotatable relative to each other with an outer periphery of the output shaft in sliding contact with an inner periphery of a cylindrical portion of the housing.

[0026] With this arrangement, since an oil film of engine oil is present between the outer periphery of the output shaft of the electric motor and the radially inner surface of the cylindrical portion of the housing, the output shaft and the cylindrical portion of the housing can smoothly rotate relative to each other. This eliminates the necessity to provide a bearing between the output shaft and the cylindrical portion of the housing, as well as between the intermediate shaft and the cylindrical portion of the internal gear, thus reducing the number of parts of the device.

[0027] Sliding portions of the outer periphery of the intermediate shaft and a radially inner surface of the cylindrical portion of the internal gear may be coated with films having improved wear resistance. Alternatively or in addition, sliding portions of the outer periphery of the output shaft of the electric motor and a radially inner surface of the cylindrical portion of the housing may be coated with films having improved wear resistance.

[0028] With this arrangement, at the sliding portions, since the coating films are in contact with each other, it is possible to reduce wear compared to the case in which the sliding surfaces are in direct contact with each other.

ADVANTAGES OF THE INVENTION

[0029] According to the present invention, the speed reduction mechanism alone can both reduce the rotational speed of the output shaft of the electric motor and transmit the thus reduced rotation of the output shaft to the camshaft. The speed reduction mechanism is thus simple in structure and thus its installation space is small. Even if the speed reduction mechanism malfunctions, the relative rotation between the camshaft and the sprocket can be limited to a predetermined angular range.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

Fig. 1 is a sectional view of a variable valve timing device according to Embodiment 1 of the present invention.

Fig. 2 is a sectional view taken along line A-A of Fig. 1.

Fig. 3 is a sectional view taken along line B-B of Fig. 1.

Fig. 4 is a sectional view of a variable valve timing device according to Embodiment 2.

Fig. 5 is a sectional view taken along line C-C of Fig. 4.

Fig. 6 is a sectional view of a variable valve timing device according to Embodiment 3.

Fig. 7 is a sectional view of Modification 1 of Embodiment 3.

Fig. 8 is a sectional view of Modification 2 of Embodiment 3.

Fig. 9 is a sectional view of a variable valve timing device according to Embodiment 4.

Fig. 10 is a sectional view of Modification 1 of Embodiment 4.

Fig. 11 is a sectional view of Modification 2 of Embodiment 4.

Fig. 12 is a sectional view of a conventional variable valve timing device.

Fig. 13 is a sectional view taken along line D-D of Fig. 12.

BEST MODE FOR EMBODYING THE INVENTION

[0031] Now referring to Figs. 1 and 2, description is made of the variable valve timing device according to Embodiment 1 of the present invention.

EMBODIMENT 1

[0032] Embodiment 1 comprises a camshaft 1 for driving intake valves (not shown), a sprocket 2 which is coaxial with the camshaft 1 and through which the revolution of the engine is transmitted to the camshaft 1, an electric motor 3 having an output shaft 4 which is coaxial with

the camshaft 1, and a speed reduction mechanism 5 through which the rotation of the output shaft 4 is transmitted to the camshaft 1, whereby it is possible to change the angular position of the camshaft 1 relative to the sprocket 2, thereby changing the timing of opening and closing of the intake valves.

[0033] The rotation of the crankshaft of the engine is transmitted to the sprocket 2 through a timing chain (not shown). Embodiment 1 further includes a housing 7 having a cylindrical portion fixed to one end surface of the sprocket 2 so as to be coaxial with the sprocket 2. The housing 7 is a cylindrical member having a first closed end and a second open end. Near the first closed end of the cylindrical portion, the output shaft 4 of the electric motor 3 is rotatably and coaxially supported by the camshaft 1 through an output shaft support bearing 11. At the second open end, the cylindrical portion of the housing 7 is fixed to the sprocket 2. The output shaft support bearing 11 is a ball bearing.

[0034] The output shaft 4 of the electric motor 3 carries an eccentric shaft portion 6 having a circular cross-section at its second end around which a ball bearing 12 is fixedly fitted. An axial through hole 4a is formed in the eccentric shaft portion 6 at its portion of which the radial dimension from the axis of output shaft 4 is maximum. The through hole 4a allows smooth and balanced rotation of the eccentric shaft portion 6.

[0035] As shown in Figs. 1 and 2, the speed reduction mechanism 5 comprises the eccentric shaft portion 6 of the output shaft 4 of the electric motor 3, an internal gear 8 fixed to the inner surface of the cylindrical portion of the housing 7, which is fixed to the sprocket 2, a plurality of rollers 9 disposed between the internal gear 8 and the radially outer portion of the eccentric shaft portion 6 and adapted to roll while being kept in contact with the teeth 8a of the internal gear 8, and an intermediate shaft 10 having an annular retainer portion 10b formed with circumferentially equidistantly arranged pockets 10a each holding one roller 9.

[0036] The internal gear 8 is coaxial with the camshaft 1 with its teeth 8a arranged at equal pitches so as to radially face the radially outer surface of the outer race of the ball bearing 12. The internal gear 8 has at least one axial protrusion 8b formed at one end surface and engaged in an axial engaging hole 7a, thus rotationally fix the internal gear 8 to the housing 7.

[0037] The teeth 8a are formed on the inner periphery of the internal gear 8 at its first end portion. In the embodiment of Fig. 2, the internal gear 8 has 29 teeth 8a. The rollers 9 are rollably disposed between the teeth 8a and the ball bearing 12 of the eccentric shaft portion 6 at the first end portion of the internal gear 8 so as to be kept in contact with the teeth 8a and the bearing 12.

[0038] Each tooth 8a of the internal gear 8 has a profile that coincides with the locus of the radially outermost portion of each roller 9, which is parallel to the locus of the center of the roller 9, when the output shaft 4 of the electric motor 3 rotates and the rollers 9 revolve around

the shaft 4 along the outer periphery of the ball bearing 12 of the eccentric shaft portion 6.

[0039] The rollers 9 are retained in the respective circumferentially equidistantly spaced apart pockets 10a of the retainer portion 10b of the intermediate shaft 10. The pockets 10a are provided at all or some of the circumferentially spaced apart points which are greater or fewer in number by one than the number of the teeth 8a. In the embodiment of Fig. 2 for example, the retainer portion 10b has 15 pockets 10a which are each located at every other one of 30 circumferentially equidistantly spaced apart points, which are larger in number by one than the 29 teeth 8a.

[0040] The intermediate shaft 10 is an annular member which is rotatably supported by an intermediate shaft support bearing 13 in the form of a ball bearing mounted in the cylindrical portion of the internal gear 8 at its second axial end. The intermediate shaft 10 has a flange 10c extending from its radially inner surface at its first axial end and in engagement with a small-diameter portion 1a of the camshaft 1 at its first axial end.

[0041] A coupling pin 14 extends axially through the flange 10c of the intermediate shaft 10 and is inserted and fixed in a fixing hole 1b formed in the shoulder defining the small-diameter portion 1a of the camshaft 1, thereby rotationally fixing the intermediate shaft 10 to the camshaft 1.

[0042] A bolt 16 is tightened in a threaded hole 1c formed in the center of the small-diameter portion 1a of the camshaft 1 with a washer 15 disposed between the small-diameter portion 1a and the bolt. When the bolt 16 is tightened, the washer 15 presses the flange 10c against the camshaft 1, thereby more reliably fixing the intermediate shaft 10 to the camshaft 1.

[0043] The intermediate shaft 10, which is fixed to the camshaft 1, is formed with an axial through hole 10d in which a stopper pin 17 is inserted and fixed in position with its end portion protruding from the second end of the intermediate shaft 10.

[0044] Instead of inserting the stopper pin 17 into the through hole 10d with its end protruding from the intermediate shaft 10 as in Embodiment 1, the intermediate shaft 10 may be formed by forging so that a protruding portion identical in shape to the protruding end portion of the stopper pin 17 is integrally formed on the intermediate shaft 10 when forming the intermediate shaft 10 by forging.

[0045] The camshaft 1 has an integral flange 1d on its outer periphery which axially retains the sprocket 2 in position so as to be rotatable relative to the camshaft 1. As shown in Fig. 3, the sprocket 2 is formed with a circumferentially elongated recess 18 in which the stopper pin 17 of the intermediate shaft 10 is engaged.

[0046] Since the recess 18 is elongated in the circumferential direction, the stopper pin 17 is movable in the circumferential direction within the range defined by the circumferential length of the recess 18. In other words, the relative rotation angle range between the intermedi-

ate shaft 10 and the sprocket 2 is restricted within θ between the two dot-and-dash lines in Fig. 3 which connect the center O of the sprocket 2 to the center of the stopper pin 17 when the pin 17 is in abutment with the respective circumferential ends of the elongated recess 18 (θ is 30° in Fig. 3). Thus the relative rotation angle range between the camshaft 1 and the sprocket 2 is also restricted to θ because the camshaft 1 is rotationally fixed to the intermediate shaft 10.

[0047] In Fig. 3, the means for restricting the relative rotation angle range comprises the stopper pin 17 provided on the intermediate shaft 10 and the recess 18 formed in the sprocket 2. But instead, a stopper pin may be provided on the sprocket 2 and a recess may be formed in the intermediate shaft 10 so that the stopper pin is engaged in the recess.

[0048] Now the operation of Embodiment 1 is described.

When the engine is started, and the engine revolution is transmitted to the sprocket 2 through the timing chain, the housing 7 is rotated together with the sprocket 2. The internal gear 8 in the housing 7 is thus also rotated together with the housing 7.

[0049] When the internal gear 8 rotates, the rollers 9 engage some of the teeth 8a and the outer periphery of the ball bearing 12, the rollers 9 rotate the retainer portion 10b, which retains the rollers 9, thus rotating the camshaft 1 through the intermediate shaft 10. In this state, in order to prevent circumferential movement of the rollers 9 relative to the internal gear 8, the electric motor 3 is rotated in synchronization with the sprocket 2. Thus, the camshaft 1 and the sprocket 2 also rotate in synchronization with each other.

[0050] When the engine revolution decreases e.g. to idling later, in order to change the timing at which the intake valves are driven by the camshaft 1, the output shaft 4 of the electric motor 3 is rotated faster or slower than the sprocket 2, i.e. rotated relative to the sprocket 2, by electronic control or any other known means.

[0051] As shown in Fig. 2, an annular space between the radially outer surface of the outer race of the ball bearing 12 and the internal gear 8 has diametrically opposed narrowest and widest portions A and B. In Fig. 2, the narrowest and widest portions A and B are located at the 12 and 6 o'clock positions, respectively. When the output shaft 4 is rotated clockwise relative to the sprocket 2 in this state, the narrowest and widest portions A and B both rotate clockwise, which means that any portion on the right-hand side of the annular space decreases in width until the narrowest portion A passes and any portion on the left-hand side of the annular space increases in width until the widest portion B passes.

[0052] At this time, the rollers 9 on the right-hand side of the annular space are pushed by the outer periphery of the outer race of the ball bearing 12 and moved radially outwardly from the apexes of the teeth 8a toward their bottoms, while the rollers 9 on the left-hand side of the annular space are moved radially inwardly from the bot-

toms of the teeth 8a toward their apexes. The rollers 9 thus revolve clockwise along the outer periphery of the ball bearing 12 as shown by the arrow in Fig. 2.

[0053] The retainer portion 10b of the intermediate shaft 10, which retains the rollers 9, thus also rotates clockwise as does the output shaft 4. When the output shaft 4 rotates counterclockwise relative to the sprocket 2, the narrowest and widest portions A and B of the annular space also rotate counterclockwise, so that the retainer portion 10b of the intermediate shaft 10, which retains the rollers 9, also rotates counterclockwise, as does the output shaft 4.

[0054] In this embodiment, since the number N of the above-mentioned circumferentially equidistantly spaced apart points is greater by one than the number of the teeth 8a of the internal gear 8, every time the output shaft 4 rotates 360 degrees relative to the internal gear 8, each roller 9 revolves in the same direction as the output shaft 4 by the distance equal to the pitch of the adjacent teeth 8a. Thus, the speed reduction ratio between the output shaft 4 and the intermediate shaft 10 is equal to the number N of the above circumferentially equidistantly spaced apart points. If this number N is smaller than the number of the teeth 8a by one, the rollers 9 revolve around the output shaft 4 in the direction opposite to the rotational direction of the output shaft 4, so that the intermediate shaft 10 also rotates in the direction opposite to the rotational direction of the output shaft 4.

[0055] When the intermediate shaft 10 rotates at a reduced rate, the camshaft 1 rotates relative to the sprocket 2, thereby changing the angular position of the camshaft 1 relative to the sprocket 2 so as to be suitable during a low-speed revolution of the engine. This stabilizes the engine revolution and improves gas mileage while the engine is idling.

[0056] When the engine revolution increases from idling to e.g. high-speed revolution, the difference in rotational speed between the sprocket 2 and the output shaft 4 of the electric motor 3 is increased, thereby again changing the angular position of the camshaft 1 relative to the sprocket 2 so as to be suitable during high-speed revolution of the engine, allowing higher output of the engine.

[0057] Thus, the speed reduction mechanism 5 reduces the revolving speed of the rollers 9 by reducing the rotational speed of the output shaft 4 of the electric motor 3, thereby reducing the rotational speed of the camshaft 1 through the intermediate shaft 10. This eliminates the need to combine a speed reduction mechanism for reducing the rotation of the output shaft of the electric motor and a link mechanism for transmitting the reduced rotation to the camshaft, thus simplifying the structure of the speed reduction mechanism 5.

[0058] In Embodiment 1, as shown in Fig. 3, due to the engagement of the stopper pin 17 of the intermediate shaft 10 in the engaging recess 18 of the camshaft 1, the relative rotation between the intermediate shaft 10 and the sprocket 2 is restricted within the angle θ , which is

the angle between the lines connecting the center O of the sprocket 2 to the center of the stopper pin 17 when the pin 17 is in abutment with the respective circumferential ends of the recess 18.

[0059] Thus, even if it becomes impossible to transmit the rotation of the sprocket 2 to the camshaft 1 through the intermediate shaft 10 due to trouble of the reduction mechanism 5, the angular position of the camshaft 1 relative to the sprocket 2 can be restricted within the angle θ because the camshaft 1 is rotationally fixed to the intermediate shaft 10.

EMBODIMENT 2

[0060] The variable valve timing device according to Embodiment 2 is now described with reference to Figs. 4 and 5.

Embodiment 2 has means for restricting the angular position of the camshaft 1 relative to the sprocket 2 which differs from that of Embodiment 1. Otherwise, Embodiment 2 is identical in structure to Embodiment 1. Thus like elements are denoted by identical numerals and their description is omitted.

[0061] Specifically, in Embodiment 2, as shown in Fig. 4, the sprocket 2 is formed with axial through hole 2b into which a stopper pin 17 is inserted and fixed in position with one end portion protruding from the hole 2b. But instead, a protrusion similar in shape to the protruding end of the stopper pin 17 may be formed on the sprocket 2 when forming the sprocket 2 by forging. In this case, the stopper pin 17 and the through hole 2b are not necessary.

[0062] As shown in Fig. 5, the flange 1d of the camshaft 1 is formed with a circumferentially extending, radially outwardly opening recess 18 in which the stopper pin 17 of the sprocket 2 engages.

[0063] The stopper pin 17 is thus circumferentially movable within the range defined by the circumferentially extending recess 18 (i.e. the range between two dash-and-dot lines in Fig. 5). In other words, the relative rotation angle range between the sprocket 2 and the camshaft 1 is restricted within the angle θ between the above two dash-and-dot lines, which connects the center O of the sprocket 2 to the center of the stopper pin 17 when the pin 17 is in abutment with the respective circumferential ends of the recess 18 (θ is 30° in Fig. 5).

[0064] In Embodiment 2, the means for restricting the angular position of the camshaft relative to the sprocket comprises the stopper pin 17 fixed to the sprocket 2 and the recess 18 formed in the camshaft 1. But instead, the stopper pin 17 may be fixed to the camshaft 1 and engaged in a recess similar to the recess 18 and formed in the sprocket 2.

[0065] In Embodiment 2 too, even if it becomes impossible to transmit the rotation of the sprocket 2 to the camshaft 1 through the intermediate shaft 10 due to trouble of the reduction mechanism 5, the angular position of the camshaft 1 relative to the sprocket 2 can be restricted

within the angle θ as in Embodiment 1.

EMBODIMENT 3

[0066] The variable valve timing device according to Embodiment 3 is now described with reference to Figs. 6 to 8.

Embodiment 3 differs from Embodiment 1 in that the camshaft 1 has an oil passage 20 through which engine oil flows, and that the sprocket 2 is formed with another oil path 21 through which engine oil from the oil passage 20 is supplied to the speed reduction mechanism 5. Otherwise, this embodiment is structurally identical to Embodiment 1. Thus, like elements are denoted by identical numerals and their description is omitted.

[0067] Engine oil is ordinarily circulated through an oil sump to every component part of the engine to ensure lubricity. In Embodiment 3, the oil passage 20 of the camshaft 1 communicates with the oil sump. Thus, engine oil is supplied from the oil sump to the component parts of the speed reduction mechanism 5 through the oil passage 20 and the oil path 21 of the sprocket 2.

[0068] The oil passage 20 extends through the axis of the camshaft 1 and communicates with the threaded hole 1c for the bolt 16. The oil passage 20 has a radial branch extending from the area near the tip of the bolt 16 and open to the outer periphery of the camshaft 1.

[0069] An oil reservoir 22 having a larger diameter than the oil passage 20 may be provided at the radially inner end of the radial branch. By providing the oil reservoir 22, it is possible to smoothly and quickly supply engine oil stored in the oil reservoir 22 to the speed reduction mechanism 5 especially when the engine is started or during hard acceleration of the engine, at which time it is usually difficult to supply enough oil to the mechanism 5.

[0070] An oil filter 23 may be provided in the oil passage 20 to remove foreign matter that enters the oil passage 20 from outside, such as metal dust contained in engine oil circulating through the engine, thereby preventing deterioration in the lubricating ability.

[0071] The oil path 21 extends between the inner peripheral surface of the sprocket 2 and its second end surface, and communicates at its end at the inner peripheral surface of the sprocket 2 with the opening of the oil passage 20 at the outer periphery of the camshaft 1, and faces the intermediate shaft supporting bearing 13 in the housing 7 at its end at the second end surface of the sprocket 2.

[0072] Since the oil path 21 is open at the second end surface of the sprocket so as to face the intermediate shaft support bearing 13, it is possible to supply engine oil that flows through the oil path 21 to the intermediate shaft support bearing 13. While the intermediate shaft 10 is rotating, since the output shaft support bearing 11 also rotates, it is possible to effectively supply engine oil to every component parts of the speed reduction mechanism 5.

[0073] In Fig. 6, the output shaft support bearing 11 and the intermediate support shaft 13 of the speed reduction mechanism 5 are ball bearings. But these bearings may be slide bearings as shown in Fig. 7, which comprise inner and outer races adapted to slide on each other through an oil film and are simpler in structure than ball bearings, provided it is possible to supply enough engine oil to every component parts of the speed reduction mechanism 5 and thus to ensure sufficient lubricity so that the output shaft 4 of the electric motor 3 and the intermediate shaft 10 can be smoothly rotated.

[0074] Alternatively, only either one of the output shaft support bearing 11 and the intermediate shaft support bearing 13 may be a slide bearing, depending e.g. on the reduction ratio of the speed reduction mechanism 5 and/or the rotational speed of the output shaft 4 of the electric motor 3.

[0075] In this embodiment, if it is possible to smoothly rotate the output shaft 4 of the electric motor 3 and the intermediate shaft 10, the intermediate shaft support bearing 13 may be omitted, and instead, as shown in Fig. 8, the intermediate shaft 10 and the internal gear 8 may be arranged so as to be rotatable relative to each other with the outer periphery of the intermediate shaft 10 and the inner periphery of the cylindrical portion of the internal gear 8 in sliding contact with each other. Further alternatively, instead of providing the output shaft support bearing 11, the output shaft 4 of the electric motor 3 and the housing 7 may be arranged so as to be rotatable relative to each other with the outer periphery of the output shaft 4 and the inner periphery of the cylindrical portion of the housing 7 in sliding contact with each other.

[0076] In either of the above arrangements, since engine oil is supplied to every component part of the speed reduction mechanism 5, an oil film forms between the slide contact surfaces of the intermediate shaft 10 and the cylindrical portion of the internal gear 8 and/or between the slide contact surfaces of the output shaft 4 and the inner periphery of the cylindrical portion of the housing 7, allowing smooth rotation of the intermediate shaft 10 and the output shaft 4 relative to the internal gear and the housing. Both of the above two arrangements may be used or only either one of the above two arrangements may be used.

[0077] The sliding surfaces of the intermediate shaft 10 and the cylindrical portion of the internal gear 8 and/or the sliding surfaces of the output shaft 4 and the inner periphery of the cylindrical portion of the housing 7 may be coated with films having improved wear resistance such as chrome plating or diamond-like carbon (DLC). With this arrangement, at the sliding portions, since the coating films are in contact with each other, it is possible to reduce wear compared to the case in which the sliding surfaces are in direct contact with each other.

EMBODIMENT 4

[0078] The variable valve timing device according to

Embodiment 4 is now described with reference to Figs. 9 to 11.

Embodiment 4 differs from Embodiment 2 in that the camshaft 1 has an oil passage 30 through which engine oil flows, and that the sprocket 2 is formed with another oil path 31 through which engine oil from the oil passage 30 is supplied to the speed reduction mechanism 5, in the same manner as Embodiment 3 differs from Embodiment 1.

Otherwise, this embodiment is structurally identical to Embodiment 2. Thus, like elements are denoted by identical numerals and their description is omitted.

[0079] As in Embodiment 3, the oil passage 30 of the camshaft 1 communicates with the oil sump. Thus, engine oil is supplied from the oil sump to the component parts of the speed reduction mechanism 5 through the oil passage 30 and the oil path 31 of the sprocket 2, thus ensuring lubricity of the component parts of the speed reduction mechanism 5.

[0080] The oil passage 30 extends through the axis of the camshaft 1 and communicates with the threaded hole 1c for the bolt 16. The oil passage 30 has a radial branch extending from the area near the tip of the bolt 16 and open to the outer periphery of the camshaft 1.

[0081] An oil reservoir 32 having a larger diameter than the oil passage 30 may be provided at the radially inner end of the radial branch. By providing the oil reservoir 32, it is possible to smoothly and quickly supply engine oil stored in the oil reservoir 32 to the speed reduction mechanism 5 especially when the engine is started or during hard acceleration of the engine, at which time it is usually difficult to supply enough oil to the mechanism 5.

[0082] An oil filter 33 may be provided in the oil passage 30 to remove foreign matter that enters the oil passage 30 from outside, such as metal dust contained in engine oil circulating through the engine, thereby preventing deterioration in the lubricating ability.

[0083] As in Embodiment 3, the oil path 31 extends between the inner peripheral surface of the sprocket 2 and its second end surface, and communicates at its end at the inner peripheral surface of the sprocket 2 with the opening of the oil passage 30 at the outer periphery of the camshaft 1, and faces the intermediate shaft supporting bearing 13 in the housing 7 at its end at the second end surface of the sprocket 2.

[0084] Since the oil path 31 is open at the second end surface of the sprocket so as to face the intermediate shaft support bearing 13, it is possible to supply engine oil that flows through the oil path 31 to the intermediate shaft support bearing 13. While the intermediate shaft 10 is rotating, since the output shaft support bearing 11 also rotates, it is possible to effectively supply engine oil to every component parts of the speed reduction mechanism 5.

[0085] In Fig. 9, the output shaft support bearing 11 and the intermediate support shaft 13 of the speed reduction mechanism are ball bearings. But these bearings

may be slide bearings as shown in Fig. 10, which comprise inner and outer races adapted to slide on each other through an oil film and are simpler in structure than ball bearings, provided it is possible to supply enough engine oil to every component parts of the speed reduction mechanism 5 and thus to ensure sufficient lubricity so that the output shaft 4 of the electric motor 3 and the intermediate shaft 10 can be smoothly rotated, as in Embodiment 3.

[0086] Alternatively, only either one of the output shaft support bearing 11 and the intermediate shaft support bearing 13 may be a slide bearing, depending e.g. on the reduction ratio of the speed reduction mechanism 5 and/or the rotational speed of the output shaft 4 of the electric motor 3.

[0087] In this embodiment, if it is possible to smoothly rotate the output shaft 4 of the electric motor 3 and the intermediate shaft 10, as in Embodiment 3, the intermediate shaft support bearing 13 may be omitted, and instead, as shown in Fig. 11, the intermediate shaft 10 and the internal gear 8 may be arranged so as to be rotatable relative to each other with the outer periphery of the intermediate shaft 10 and the inner periphery of the cylindrical portion of the internal gear 8 in sliding contact with each other. Further alternatively, instead of providing the output shaft support bearing 11, the output shaft 4 of the electric motor 3 and the housing 7 may be arranged so as to be rotatable relative to each other with the outer periphery of the output shaft 4 and the inner periphery of the cylindrical portion of the housing 7 in sliding contact with each other.

[0088] In either of the above arrangements, since engine oil is supplied to every component part of the speed reduction mechanism 5, an oil film forms between the slide contact surfaces of the intermediate shaft 10 and the cylindrical portion of the internal gear 8 and/or between the slide contact surfaces of the output shaft 4 and the inner periphery of the cylindrical portion of the housing 7, allowing smooth rotation of the intermediate shaft 10 and the output shaft 4 relative to the internal gear and the housing. Both of the above two arrangements may be used or only either one of the above two arrangements may be used.

[0089] The sliding surfaces of the intermediate shaft 10 and the cylindrical portion of the internal gear 8 and/or the sliding surfaces of the output shaft 4 and the inner periphery of the cylindrical portion of the housing 7 may be coated with films having improved wear resistance such as chrome plating or diamond-like carbon (DLC). With this arrangement, at the sliding portions, since the coating films are in contact with each other, it is possible to reduce wear compared to the case in which the sliding surfaces are in direct contact with each other.

DESCRIPTION OF THE NUMERALS

[0090]

1. Camshaft
- 1a. Small-diameter portion
- 1b. Fixing hole
- 1c. Threaded hole
- 1d. Flange
2. Sprocket
- 2a. Engaging recess
- 2b. Through hole
3. Electric motor
4. Output shaft
- 4a. Through hole
5. Speed reduction mechanism
6. Eccentric shaft portion
7. Housing
- 7a. Engaging hole
8. Internal gear
- 8a. Teeth
- 8b. Protrusion
9. Roller
10. Intermediate shaft
- 10a. Pocket
- 10b. Retainer portion
- 10c. Flange
- 10d. Through hole
11. Output shaft support bearing
12. Ball bearing
13. Intermediate shaft support bearing
14. Coupling pin
15. Washer
16. Bolt
17. Stopper pin
18. Engaging recess
- 20, 30. Oil passage
- 21, 31. Oil path
- 22, 32. Oil reservoir
- 23, 33. Oil filter
41. Camshaft
- 41a. Cam plate
42. Sprocket
43. Electric motor
44. Output shaft
45. Speed reduction mechanism
46. Link mechanism
- 46a. Arm
- 46b. Arm
47. Internal gear
48. Housing
49. External gear
50. Guide plate

Claims

1. A variable valve timing device comprising a camshaft for driving at least one of an intake valve and an exhaust valve of an engine, and a sprocket configured to be rotated by the engine to drive the camshaft, said camshaft and said sprocket being ar-

ranged coaxially with each other so as to be rotatable relative to each other, an electric motor having an output shaft, and a speed reduction mechanism through which the rotation of the output of the electric motor can be transmitted to the camshaft at a reduced rate, thereby changing the angular position of the camshaft relative to the sprocket,

characterized in that said speed reduction mechanism comprises an eccentric shaft portion provided on the output shaft of the electric motor and having a circular cross-section, a housing fixed to the sprocket, an internal gear fixedly mounted in the housing and having teeth, a plurality of rollers disposed between the internal gear and an outer periphery of the eccentric shaft portion, and an intermediate shaft coaxial with the camshaft and including an annular retainer portion formed with circumferentially equidistantly spaced pockets in which the respective rollers are retained, that the number of the pockets of the retainer portion is smaller or larger by one than the number of the teeth of the internal gear, that each tooth of the internal gear has a profile that coincides with the locus of the radially outermost portion of each roller which is parallel to the locus of the center of the roller, when the output shaft of the electric motor rotates and the rollers revolve around the output shaft, whereby the revolution of the rollers is transmitted to the camshaft through the intermediate shaft, and that the variable valve timing device further includes restricting means for restricting the rotation of the camshaft relative to the sprocket within a predetermined angular range.

2. The variable valve timing device of claim 1, wherein the restricting means comprises a protrusion provided on one of the intermediate shaft and the sprocket, and a circumferentially elongated engaging recess formed in the other of the intermediate shaft and the sprocket, said protrusion being engaged in the engaging recess such that the protrusion is movable within the range of the circumferential length of the engaging recess, whereby the relative rotation between the intermediate shaft and the sprocket is restricted within an angle formed between two lines connecting the center of the sprocket to the protrusion when the protrusion is at the respective extreme circumferential ends of the engaging recess.
3. The variable valve timing device of claim 1, wherein the restricting means comprises a protrusion provided on one of the sprocket and the camshaft, and a circumferentially elongated engaging recess formed in the other of the sprocket and the camshaft, said protrusion being engaged in the engaging recess such that the protrusion is movable within the range of the circumferential length of the engaging recess, whereby the relative rotation between the sprocket and the camshaft is restricted within an angle formed

between two lines connecting the center of the sprocket to the protrusion when the protrusion is at the respective extreme circumferential ends of the engaging recess.

4. The variable valve timing device of any of claims 1 to 3, wherein the camshaft is formed with an oil passage through which engine oil can pass, and the sprocket is formed with an oil path through which engine oil supplied from the oil passage can be supplied to the speed reduction mechanism.
5. The variable valve timing device of claim 4, wherein the oil passage has an oil reservoir for engine oil.
6. The variable valve timing device of claim 4 or 5, further comprising an oil filter provided in the oil passage of the camshaft.
7. The variable valve timing device of any of claims 4 to 6, further comprising an intermediate support bearing comprising a slide bearing disposed around an outer periphery of the intermediate shaft and fixedly fitted in a cylindrical portion of the internal gear.
8. The variable valve timing device of any of claims 4 to 7, further comprising an output support bearing comprising a slide bearing disposed around an outer periphery of the output shaft of the electric motor and fixedly fitted in a cylindrical portion of the housing.
9. The variable valve timing device of any of claims 4 to 6, wherein the intermediate shaft and the internal gear are rotatable relative to each other with an outer periphery of the intermediate shaft in sliding contact with an inner periphery of a cylindrical portion of the internal gear.
10. The variable valve timing device of any of claims 4 to 6 and 9, wherein the output shaft of the electric motor and the housing are rotatable relative to each other with an outer periphery of the output shaft in sliding contact with an inner periphery of a cylindrical portion of the housing.
11. The variable valve timing device of claim 9 or 10 wherein sliding portions of the outer periphery of the intermediate shaft and a radially inner surface of the cylindrical portion of the internal gear are coated with films having improved wear resistance, or sliding portions of the outer periphery of the output shaft of the electric motor and a radially inner surface of the cylindrical portion of the housing are coated with films having improved wear resistance.

Fig.1

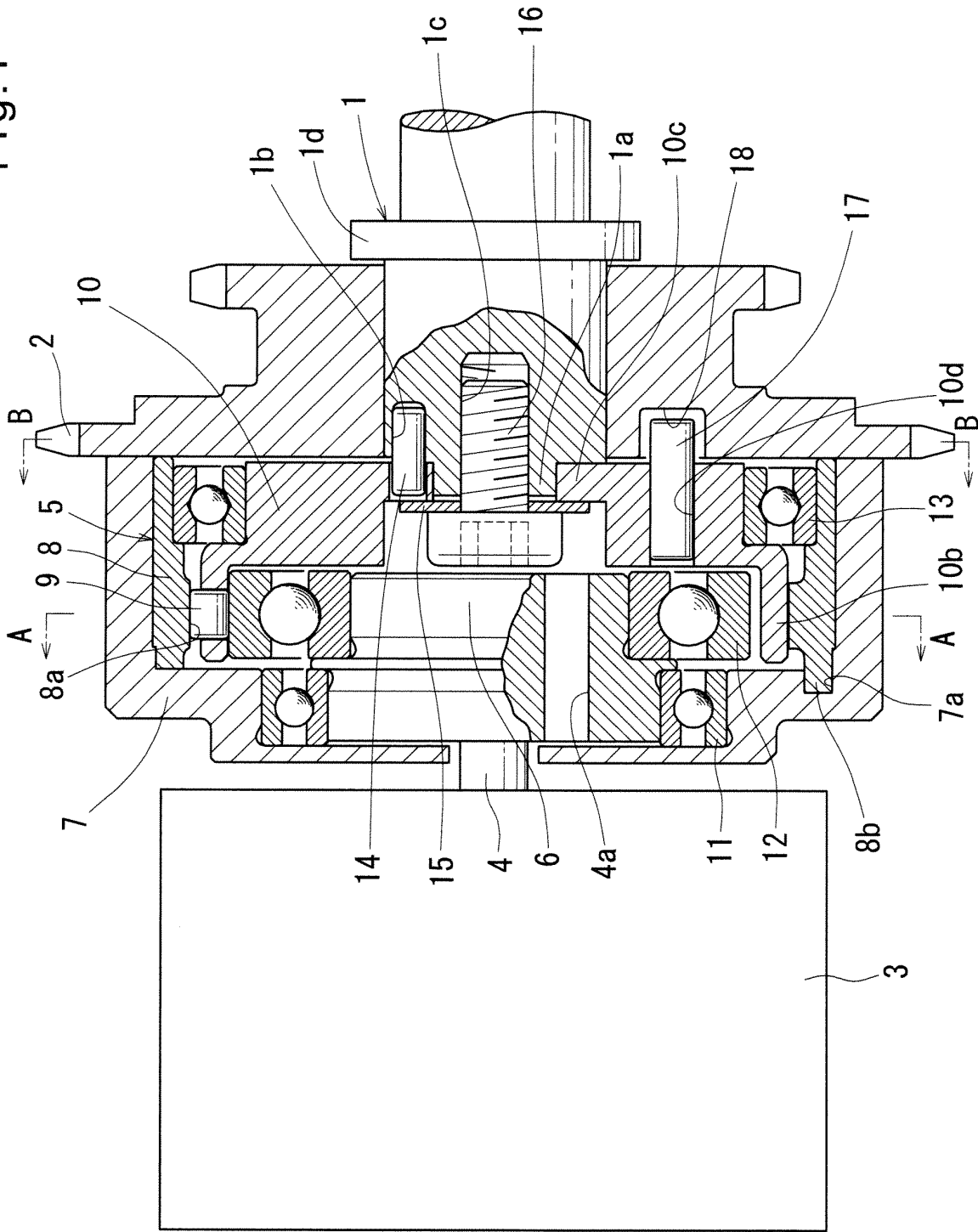


Fig.2

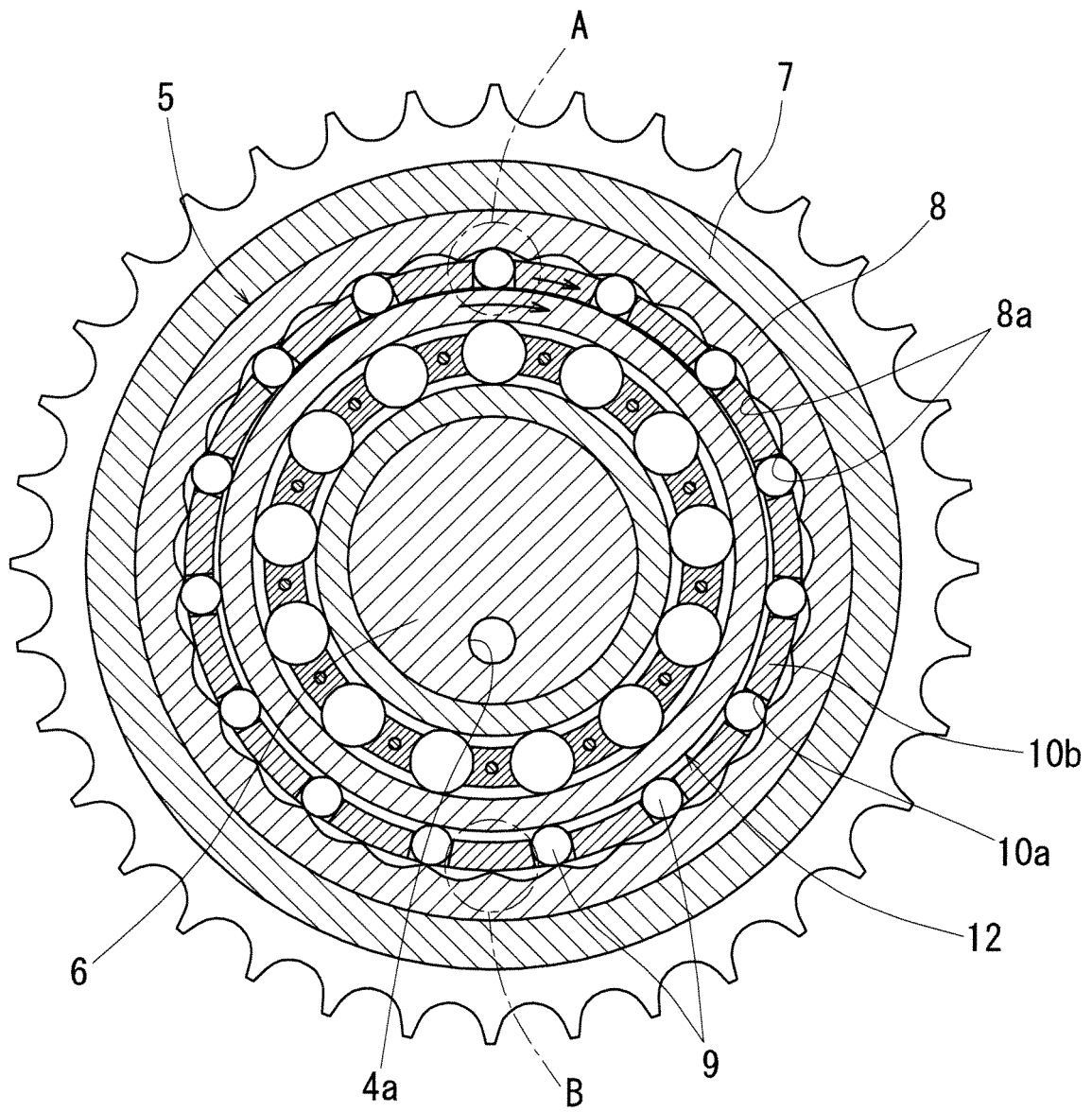


Fig.3

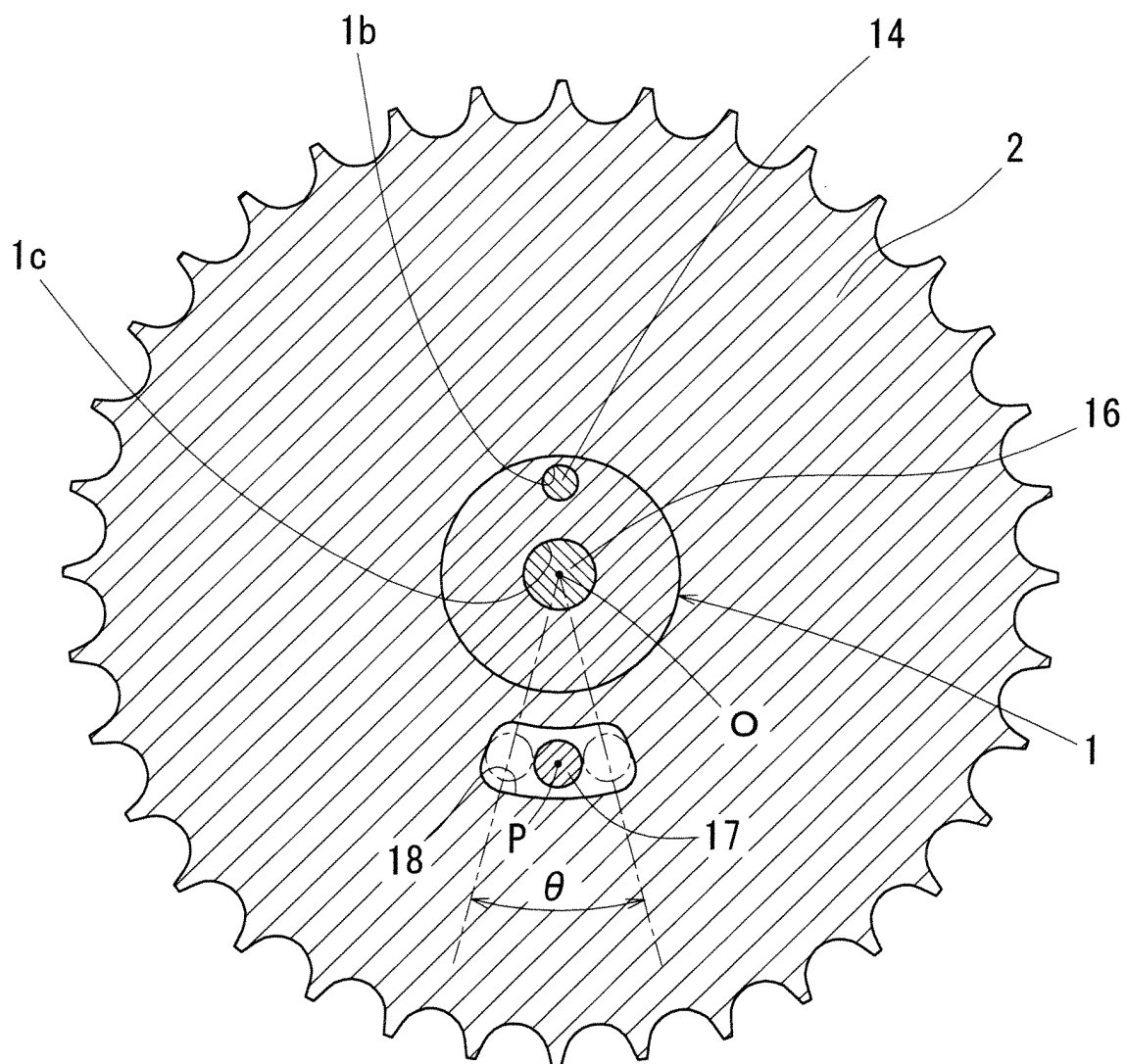


Fig.4

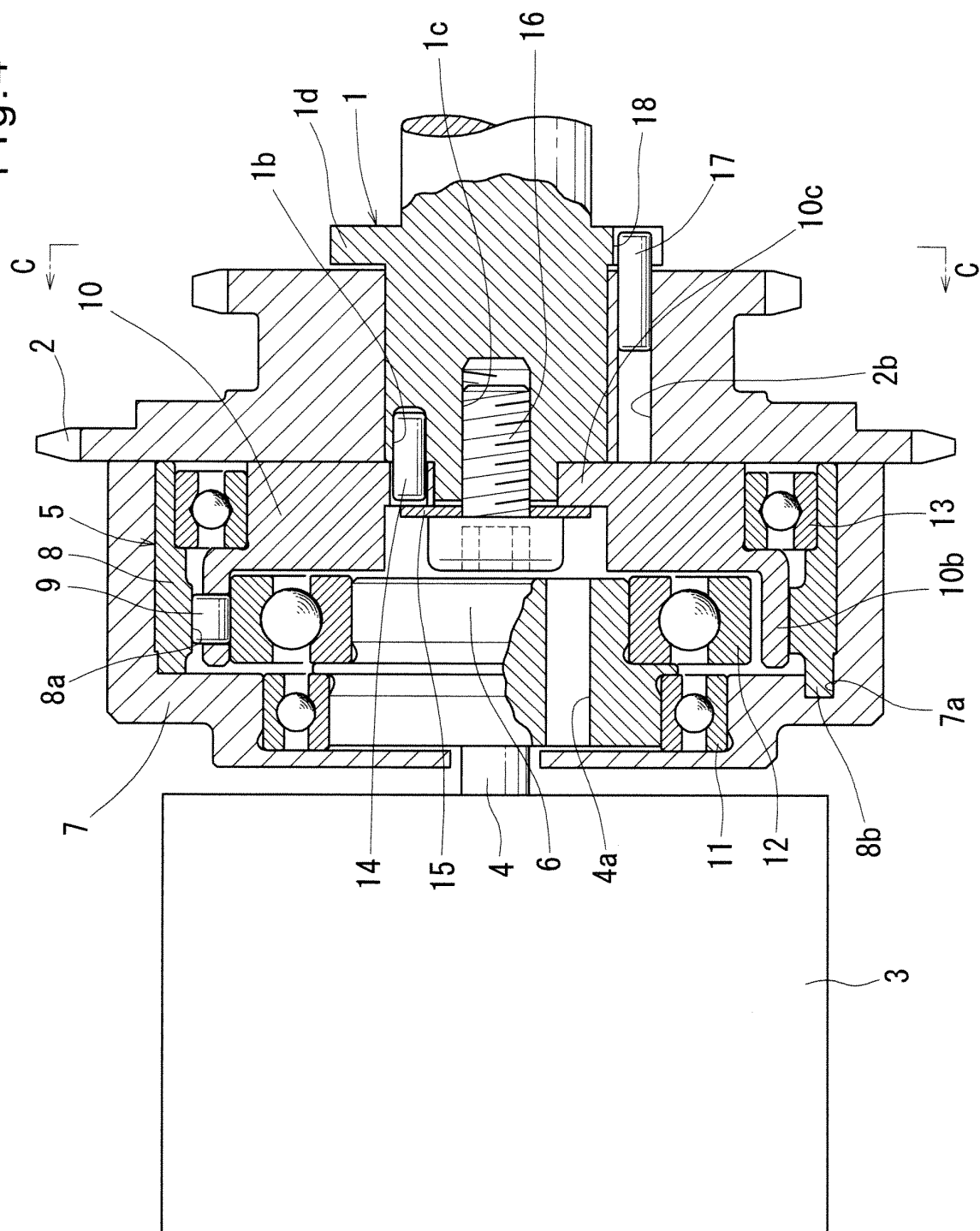


Fig.5

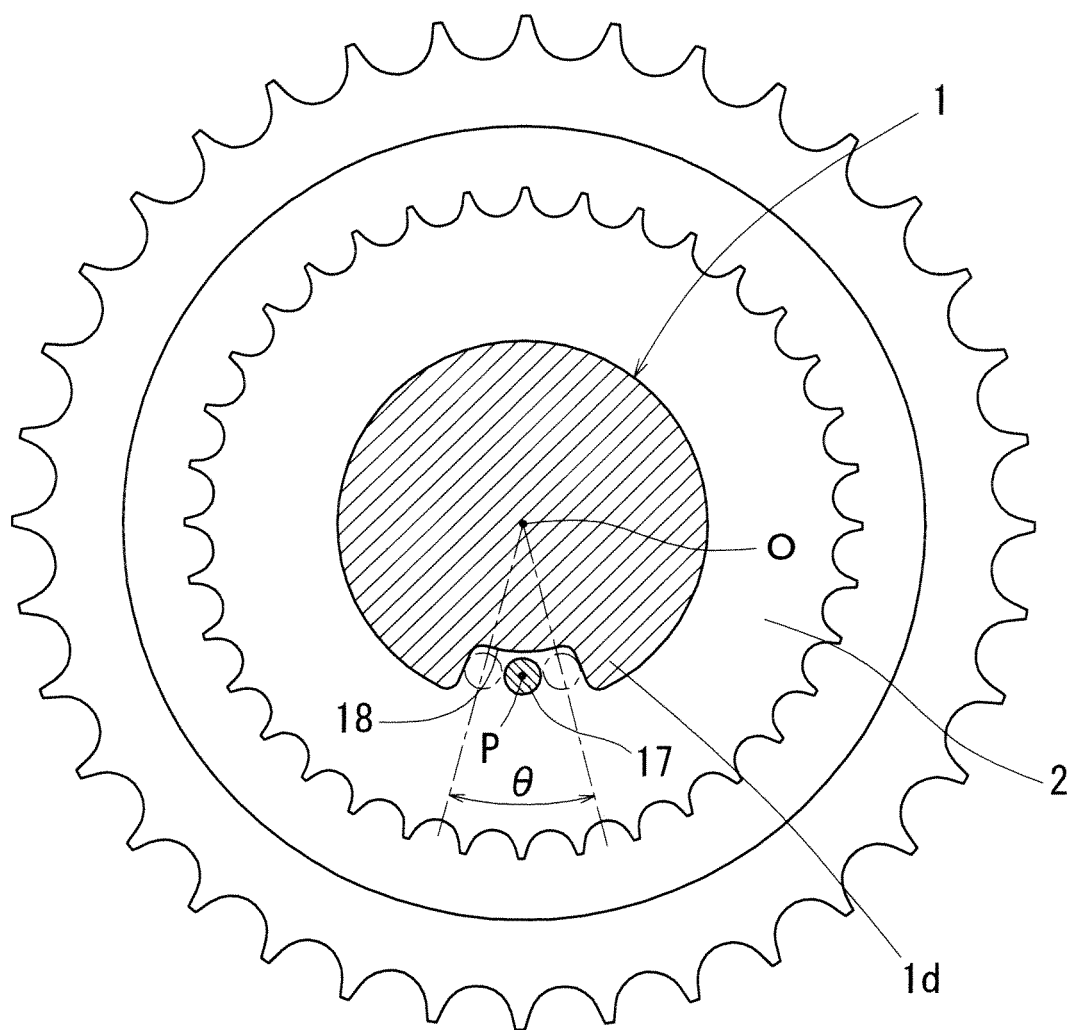


Fig. 6

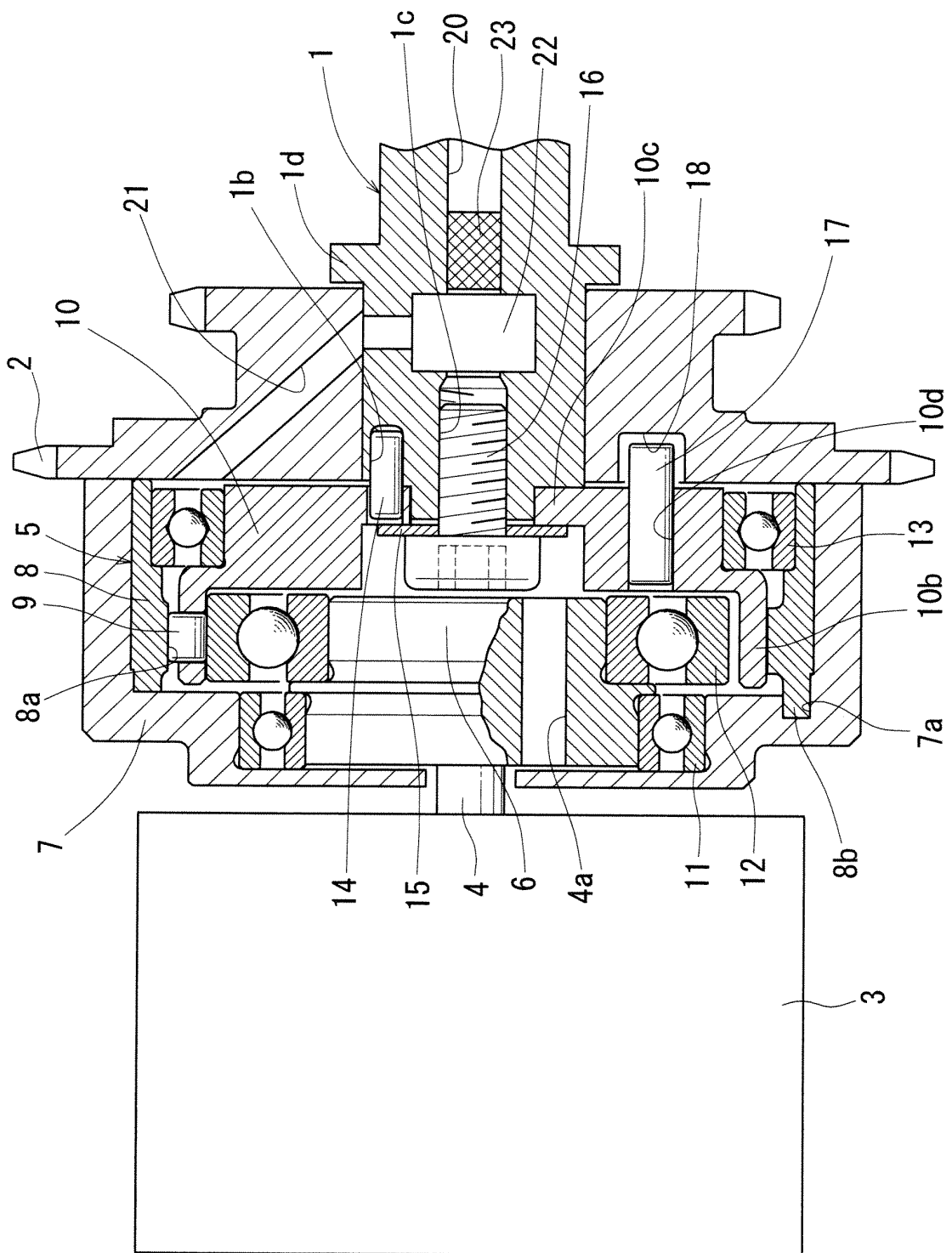


Fig.7

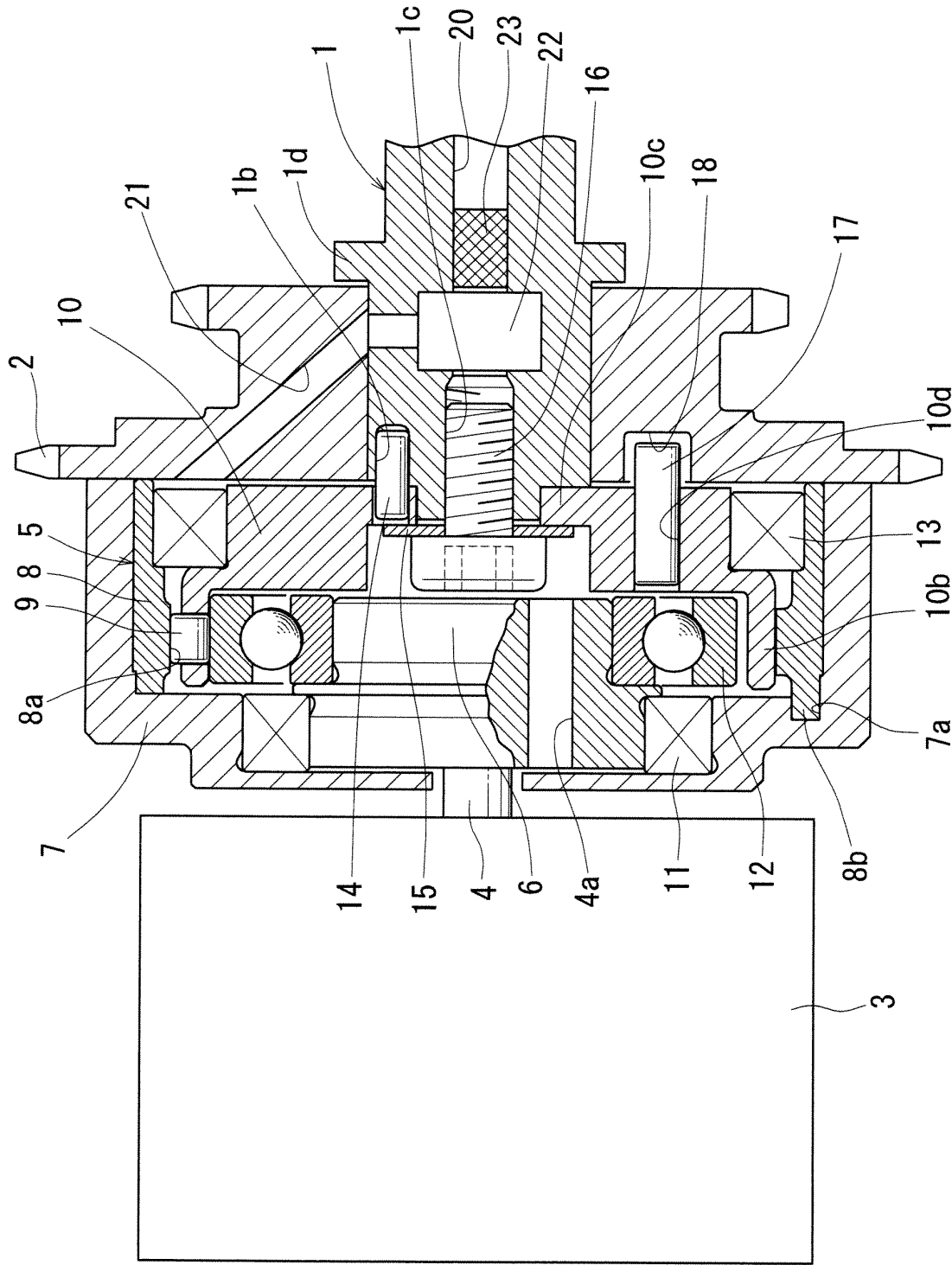


Fig.8

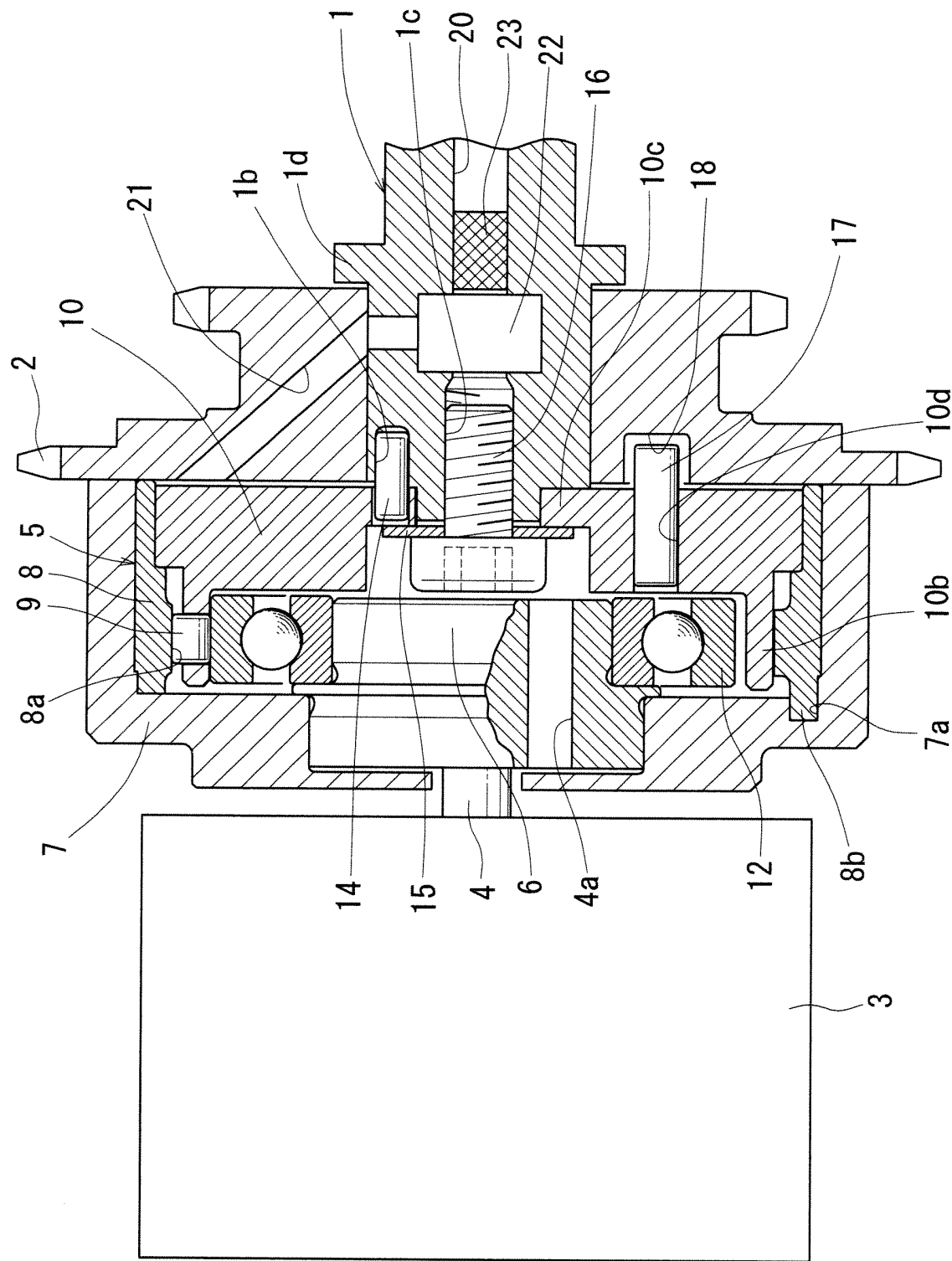


Fig.9

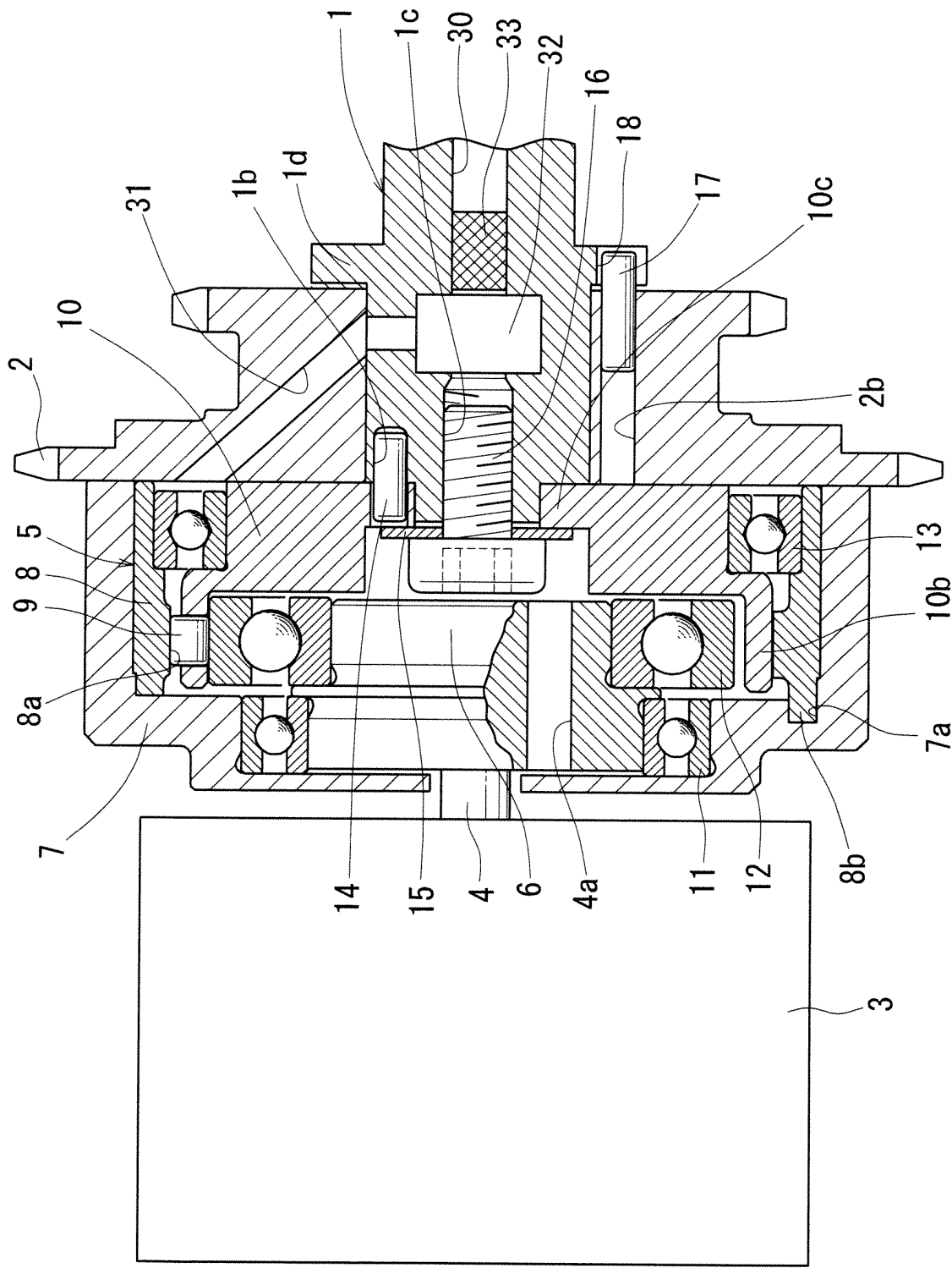


Fig. 10

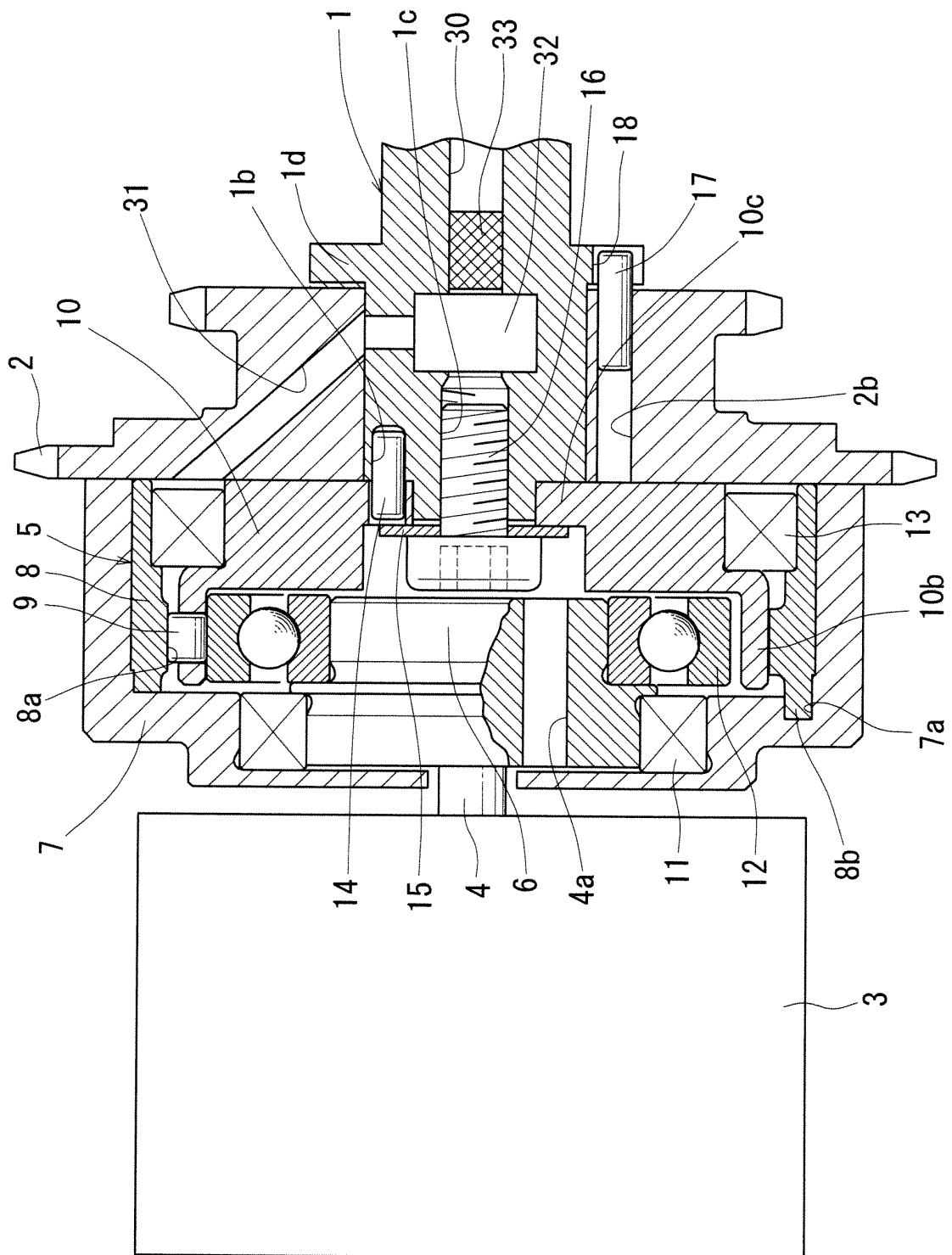


Fig.11

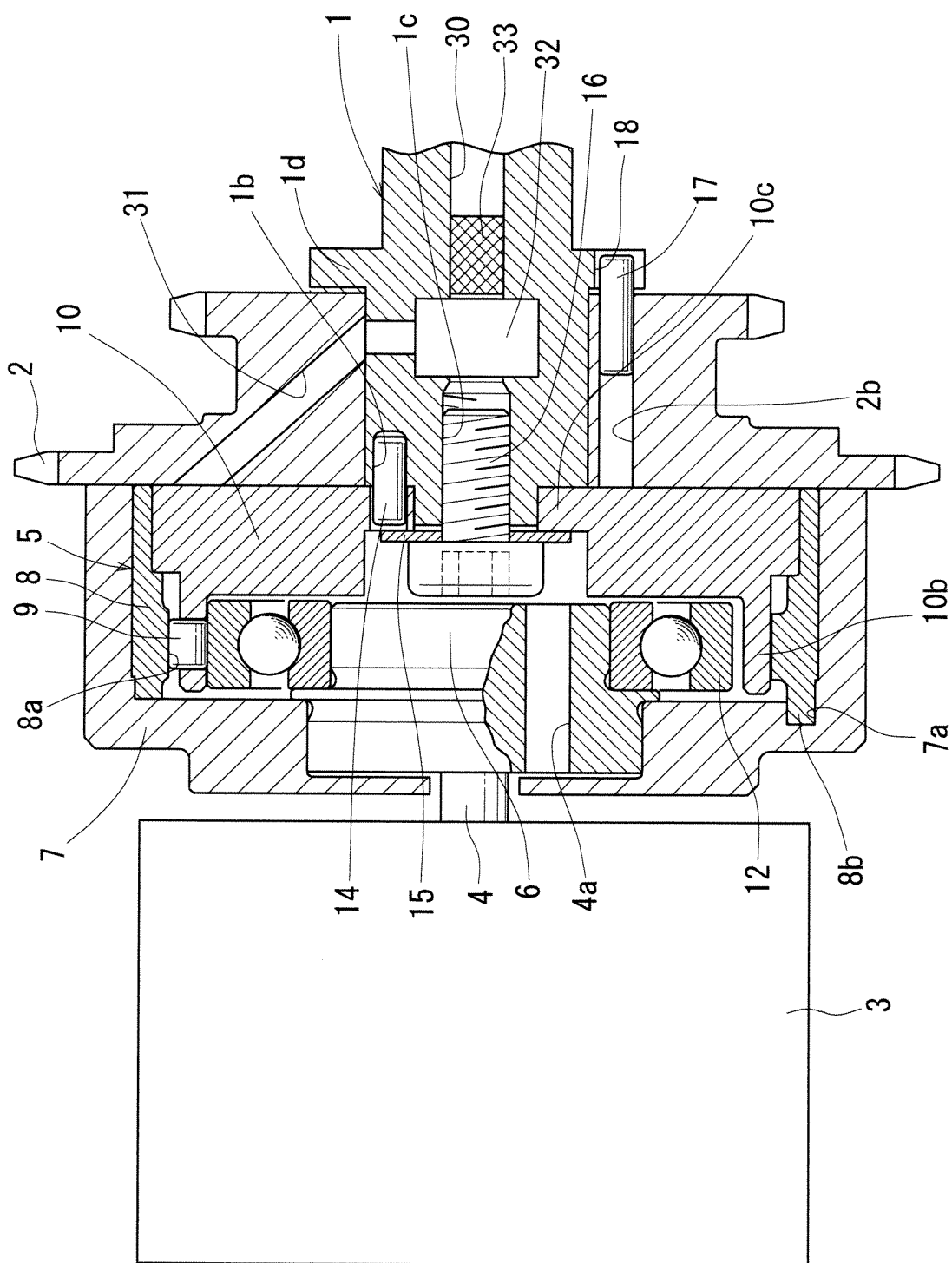


Fig. 12

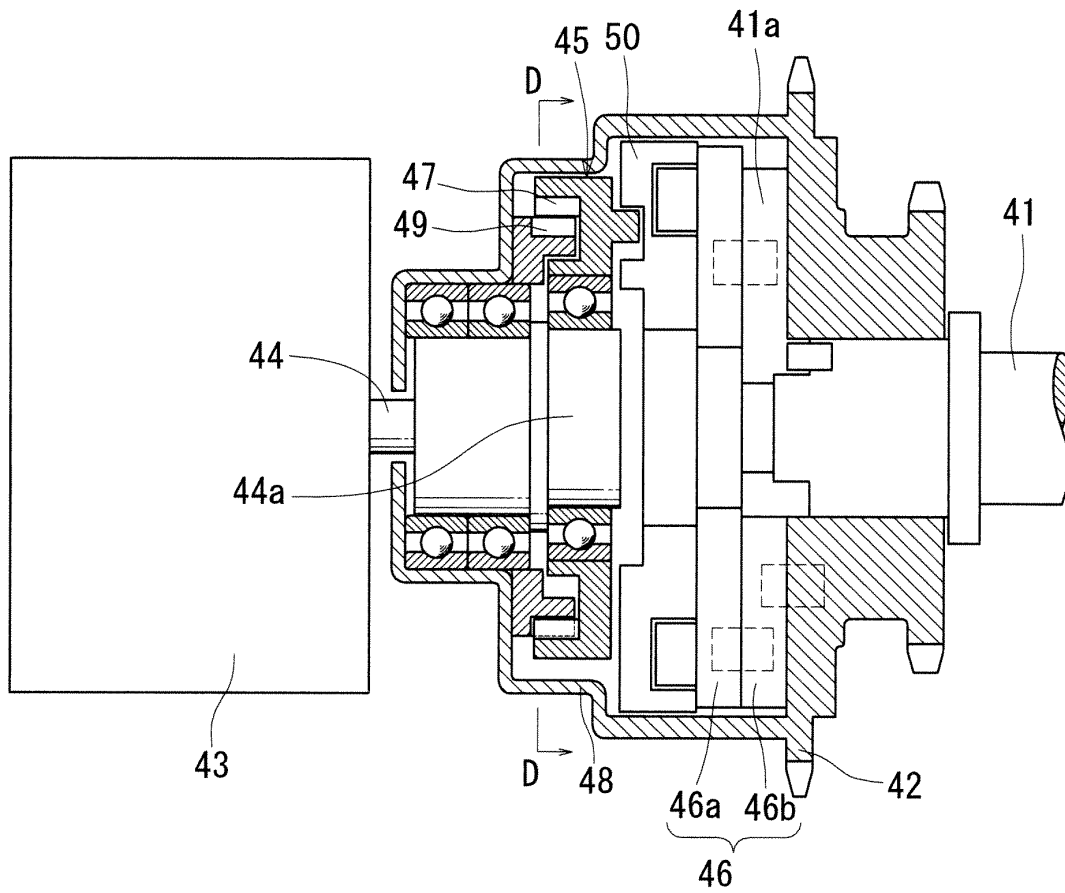
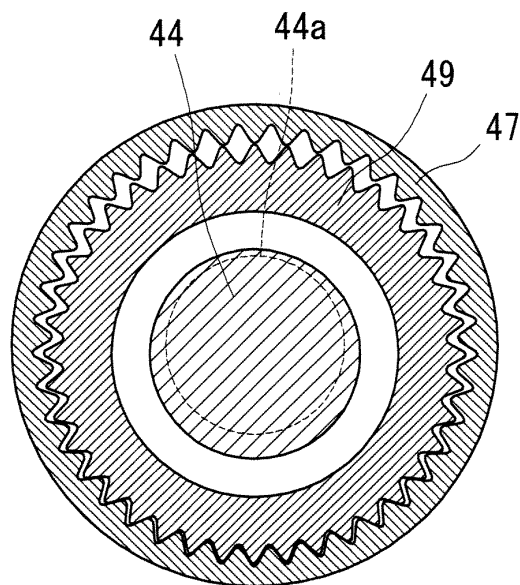


Fig. 13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/055183

A. CLASSIFICATION OF SUBJECT MATTER

F01L1/34 (2006.01) i, F16H1/32 (2006.01) i

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)

F01L1/34, F16H1/32

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2008-57349 A (Toyota Motor Corp.), 13 March 2008 (13.03.2008), paragraphs [0017] to [0085]; fig. 3 to 8 & WO 2008/029240 A1 paragraphs [0018] to [0087]; fig. 3 to 8	1-11
A	JP 2007-2777 A (Hitachi, Ltd.), 11 January 2007 (11.01.2007), paragraphs [0010] to [0082]; fig. 2 to 10 (Family: none)	1-11
A	JP 2002-221130 A (NSK Ltd.), 09 August 2002 (09.08.2002), paragraphs [0013] to [0027]; fig. 1 to 3 (Family: none)	1-11

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I" 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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
07 May, 2010 (07.05.10)Date of mailing of the international search report
18 May, 2010 (18.05.10)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/055183

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 58-174743 A (Sumitomo Heavy Industries, Ltd.), 13 October 1983 (13.10.1983), page 1, right column, line 3 to page 4, left column, line 17; fig. 1 to 6 & US 4561833 A column 4, line 52 to column 14, line 9; fig. 1 to 12 & EP 98682 A1 & DK 153383 A	1-11

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2008057349 A [0005]