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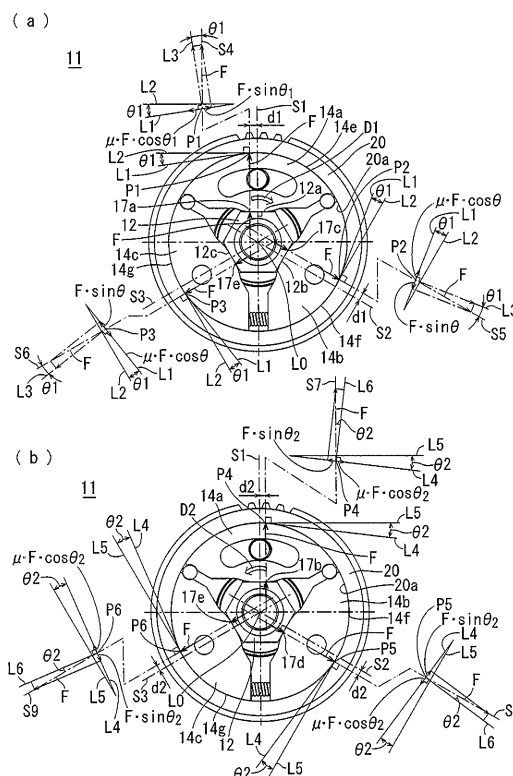
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(54) **AUTOMOTIVE ENGINE PHASE-ADJUSTING DEVICE**

(57) To provide a variable phaser for an automobile engine including a self-locking mechanism which does not hinder an operation of changing a relative phase angle of a cam shaft with respect to a drive rotating member. In a variable phaser for an automobile engine including a drive rotating member having a cylindrical section and driven by a crank shaft, a cam shaft coaxially supporting the drive rotating member in a coaxial and relatively rotating fashion, a relative phase angle changing mechanism, and a self-locking mechanism preventing the misalignment of the relative phase angle due to the cam torque by means of pressing the lock plate held on a holding section integral with the cam shaft to an inner circumferential surface of the cylindrical section, plate-pressing surfaces disposed at a plurality of positions almost equally separated along an outer circumferential direction of an outer circumference of the holding section, and a plurality of lock plates equally separated in correspondence to the plate-pressing surfaces are formed, and the respective plate-pressing surfaces are formed by first and second pressing surfaces for delivering the cam torques along advance and lag directions to the respective lock plates.

Fig. 8



Description

Technical Field

[0001] The present invention is a technique relating to a variable phaser for an automobile engine in which a self-locking mechanism for preventing the misalignment of relative phase angles caused by a cam torque generated in a cam shaft is equipped on a phase variable mechanism for changing the opening-closing timing of an engine valve by means of changing the above relative phase angle of the cam shaft with respect to a crank shaft.

Background Art

[0002] The variable phaser for the automobile engine in which the self-locking mechanism for preventing the misalignment of the relative phase angles caused by the cam torque input to the cam shaft from the engine valve side is mounted in the phase variable mechanism for changing the opening-closing timing of the engine valve by means of changing the relative phase angles of the cam shaft with respect to the crank shaft is described in Patent Publication 1..

[0003] In the variable phaser for the automobile engine of Patent Publication 1 which is shown in Fig. 1, a cam shaft is arranged in a coaxial and relatively rotating fashion with respect to a drive rotating member driven by a crank shaft, and rotates along the same direction together with the drive rotating member upon receipt of the driving force of the crank shaft.. In case of changing the opening-closing timing of the engine valve, a first control rotating member integrated with the cam shaft via a center shaft in a coaxial and relative rotation disabling fashion relatively rotates along either of an advance direction (the same direction as that of the drive rotating member, hereinafter similarly applied) or a lag direction (the direction reverse to the advance direction, hereinafter similarly applied) with respect to the drive rotating member 2 driven by a crank shaft (not shown) accompanied with the actuation of a first electromagnetic clutch or a second electromagnetic clutch via a reverse rotation mechanism. The opening-closing timing of the engine valve is changed by changing, with respect to the drive rotating member of the crank shaft side, the relative phase angle of the cam shaft connected to the first control rotating member, as described above.

[0004] On the other hand, the cam shaft is subject to cam torques generated alternatively along the advance direction and the lag direction from the engine valve due to the impact of the opening-closing of the engine valve. The cam torque is a cause of generating the misalignment in the relative phase angle of the cam shaft with respect to the drive rotating member. Accordingly, in a variable phaser of an engine of Patent Publication 1, a self-locking mechanism is mounted for preventing the above misalignment of the relative phase angle by locking the cam shaft in a relative rotation disabling fashion

with respect to the drive rotating member at a time of generation of the cam torque. The self-locking mechanism is mainly composed of an eccentric circular cam integrated with the center shaft, a lock plate, a lock plate bush equipped to the eccentric circular cam, and a pair of lock plates hold on the eccentric circular cam via the lock plate bush. The pair of the lock plates are held on the eccentric circular cam in a relative rotation disabling fashion by the eccentric circular cam, and are contacted internally to an inner circumference surface of a circular section of the drive rotating member (refer to Fig. 5 of Patent Publication 1).

[0005] In case of changing the relative phase angle of the cam shaft with respect to the drive rotating member, the pair of the lock plates connected to the first control rotating member relatively rotates with respect to the drive rotating member together with the center shaft (cam shaft) integrated with the eccentric circular cam. On the other hand, the self-locking mechanism works as follows The cam torque generated in the cam shaft generates an eccentric rotating torque around a rotating central shaft line of the cam shaft. The eccentric circular cam generates a self-locking force such that the eccentric circular cam receiving the cam torque of the advance direction presses one of the lock plates onto the inner circumferential surface of a cylindrical section of the drive rotating member via the lock plate bush while the eccentric circular cam receiving the cam torque of the lag direction presses the other lock plates onto the inner circumferential surface of the cylindrical section of the drive rotating member.

[0006] The self-locking mechanism of Patent Publication 1 generates the self-locking mechanism such that the self-locking force from the cam torque is alternately transmitted to the pair of the lock plates from the eccentric circular cam, and the cam shaft is locked in a relative rotation disabling fashion with respect to the drive rotating member by pressing the pair of the lock plates, alternately, to the cylindrical section of the drive rotating section.

Prior Technical Publications

Patent Publications

[0007] Patent Publication 1: WO2011/145175

Summary of Invention

Problems to Be Solved by Invention

[0008] In the self-locking mechanism of Patent Publication 1, the self-locking force of the cam torque is transmitted to only one of the pair of the lock plates based on the direction of the cam torque (advance or lag direction) so that only one of the lock plates can be pressed on the cylindrical section of the drive rotating member.. In case of pressing only one of the lock plates on the cylindrical section of the drive rotating member, the lock plate is

likely to dig into the inner circumferential surface of the cylindrical section of the drive rotating member as a wedge. The lock plate dug into the inner circumferential surface prevents the release of the self-locking function. In case of generating the self-locking function in only one of the lock plates, the drive rotating member rotatably supported by the center shaft (cam shaft) produces a slant with respect to the rotating central shaft line of the cam shaft. The slanted drive rotating member generates friction on the support section of the drive rotating member mounted on the center shaft

[0009] The prevention of the deactivation of the self-locking function and the generation of the friction between the drive rotating member and the center shaft are problematic in terms of the prevention of the operation of changing the relative phase angle of the drive rotating member with respect to the cam shaft.

[0010] The present invention provides a variable phaser of an automobile engine having a self-locking function free of preventing the operation of changing a relative phase angle of a cam shaft with respect to a drive rotating member of a crank shaft side.

Means of Solving Problems

[0011] An variable phaser for an automobile engine of claim 1 includes, a drive rotating member having a cylindrical section and driven by a crank shaft; a cam shaft coaxially and supporting the drive rotating member in a coaxial and relatively rotating fashion, a relative phase angle changing mechanism for changing an opening-closing timing of a valve by means of changing a relative phase angle of the cam shaft with respect to the drive rotating member; and a self-locking mechanism including a holding section integrally formed in a shape of a flange on an outer periphery of the cam shaft, and a lock plate held to the cam shaft in a relative rotation disabling fashion by the holding section and contacted internally to an inner circumference surface of the cylindrical section, in which the holding section prevents misalignment of the relative phase angle by means of pressing the lock plate onto the inner circumference surface of the cylindrical section upon receipt of a cam torque generating along an advance direction or a lag direction, characterized in that, plate-pressing surfaces pressing the lockplates are disposed at a plurality of positions almost equally separated along an outer circumferential direction of the holding section; the lock plates are mounted the same number as the plate-pressing surfaces at a plurality of positions almost equally separated along an outer circumferential direction, and include pressure receiving sections at positions opposing to the plate-pressing surfaces; and the plurality of the plate-pressing surfaces are configured by a first pressing surface pressing the lock plate upon receipt of the cam torque generating along the advance direction and a second pressing surface pressing the lock plate upon receipt of the cam torque generating along the lag direction.

(Function)

[0012] When the cam torque in the advance direction (the same direction as the drive rotating member) is input from the engine valve to the cam shaft, all of the plurality of the lock plates are pressed onto the inner circumferential surface of the cylindrical section of the drive rotating member upon receipt of the self-locking forces in a nearly radius direction of the cam shaft from the first pressing surfaces formed on the respective holding sections. Also when the cam torque in the lag direction (the reverse rotating direction with respect to the advance direction) is input from the engine valve to the cam shaft, all of the plurality of the lock plates are pressed onto the inner circumferential surface of the cylindrical section of the drive rotating member upon receipt of the self-locking forces in a nearly radius direction of the cam shaft from the second pressing surfaces formed on the respective holding sections.

[0013] That is, when the cam torque is generated, all of the plurality of the lock plates are pressed on the inner circumferential surface of the cylindrical section of the drive rotating member regardless of the direction of the cam torque so that the self-locking function uniformly acts to the inner circumferential surface of the cylindrical section of the drive rotating member.

[0014] In claim 2, each of the plate-pressing surfaces and the lock plates are disposed at three or more positions almost equally separated along the outer circumferential direction in the variable phaser for the automobile engine of claim 1.

(Function)

[0015] By disposing the three or more lock plates at the plurality of the positions almost equally separated along the circumferential direction on the inner circumferential surface of the cylindrical section of the drive rotating member, the respective lock plates are pressed toward the outside in a radius direction of the drive rotating member at the plurality of the positions almost equally separated along the circumferential direction so as to be pressed more uniformly on the all periphery of the above inner circumferential surface.

[0016] In claim 3, each of the first pressing surface and the second pressing surface are formed on the plate-pressing surface as two surfaces separated by a virtual surface passing a central shaft line of the cam shaft and perpendicular to the plate-pressing surface, the pressure receiving sections include a first acting section to which a pressing force by the first pressing surface is exerted and a second acting section to which a pressing force by the second pressing surface is exerted; and the first acting section and the second acting section are formed on the pressure receiving section such that a first distance from the virtual surface to the first acting section is different from a second distance from the virtual surface to the second acting section in the variable phaser for the

automobile engine of claim 2.

[0017] The self-locking force when the cam torque is generated in the cam shaft in the advance direction is delivered to the drive rotating member via the first acting section of the lock plate side from the first pressing surface of the cam shaft side, and the self-locking force when the cam torque is generated in the lag direction is delivered to the drive rotating member via the second acting section from the second pressing surface..

(Function)

[0018] The self-locking force acting between the lock plate and the drive rotating member passes through the central shaft line of the cam shaft and strongly exerts in proportion to the distance from the lock plate to the acting section from the virtual surface perpendicular to the plate-pressing surface.

[0019] Generally, the cam torque in the lag direction in the cam shaft is generated by an elastic force the cam receives from a valve spring when the cam presses down the engine valve, and the cam torque in the advance direction is generated by an elastic force the valve spring receives when the valve spring presses up the cam via the engine valve. Since the friction preventing the rotation (torque in lag direction) is added on a slide surface between the cam and the valve, the cam torque in the lag direction is usually larger than the cam torque in the advance direction. In this case, by making the second distance from the virtual surface to the second acting surface shorter than the first distance from the virtual surface to the first acting surface, the self-locking force based on the cam torque generated in the lag direction is stronger than the self-locking force based on the cam torque generated in the advance direction.

[0020] Depending on the kind of the engine, the cam torque in the advance direction is sometimes larger than the cam torque in the lag direction. In this case, by making the first distance from the virtual surface to the first acting surface shorter than the second distance from the virtual surface to the second acting surface, the self-locking force based on the cam torque generated in the advance direction is stronger than the self-locking force based on the cam torque generated in the lag direction.

[0021] In claim 4, the first acting section and the second acting section are formed on the pressure receiving section such that the second distance (passing through the central shaft line of the cam shaft, and from the virtual surface perpendicular to the plate-pressing surface to the second acting section) is shorter than the first distance (from the virtual surface to the first acting section) in the variable phaser for the automobile engine of claim 3

(Function)

[0022] Since the second distance is shorter than the first distance, the strong self-blocking force is generated according to the cam torque in the lag direction when the

self-blocking force is exerted on the second acting section, and the self-blocking force is generated according to the cam torque in the advance direction when the self-blocking force is exerted on the first acting section. In other words, the appropriate self-locking force is generated according to the strength of the cam torque between the lock plate and the drive rotating member..

[0023] In claim 5, the pressure receiving section is mounted on the lock plate in a freely attaching and detaching fashion in the variable phaser for the automobile engine of claim 3 or 4.

(Function)

[0024] The pressure receiving section can be replaced depending on the strength of the torque generating in the advance direction and the lag direction by preparing the plurality of the various pressure receiving sections having the different combinations of the first distance from the virtual surface to the first acting section and the second distance from the virtual surface to the second acting section.

Effects of Invention

[0025] In accordance with the variable phaser for the automobile engine of claim 1, since the self-locking function is uniformly exerted on the inner circumferential surface of the cylindrical section of the drive rotating member, the lock plate takes no dig on the inner circumferential surface of the cylindrical section. The drive rotating member at the time of generating the self-locking function makes no slant with respect to the central shaft line of the cam shaft. As a result, according to the variable phaser for the automobile engine of claim 1, the operation of changing the relative phase angle of the cam shaft with respect to the drive rotating member of the crank shaft side is not hindered.

[0026] In accordance with the variable phaser for the automobile engine of claim 2, since the self-locking function is exerted on the inner circumferential surface of the cylindrical section of the drive rotating member further uniformly, the lock plate is difficult to take the dig on the inner circumferential surface of the cylindrical section and the drive rotating member is further difficult to make the slant with respect to the central shaft line of the cam shaft. As a result, the operation of changing the relative phase angle of the cam shaft with respect to the drive rotating member of the crank shaft side is further difficult to be hindered.

[0027] In accordance with the variable phaser for the automobile engine of claim 3, since the sufficient self-locking force is obtained which corresponds to the cam torque having the different strength depending on the direction, the misalignment of the relative phase angle of the cam shaft with respect to the drive rotating member can be securely presented.

[0028] In accordance with the variable phaser for the

automobile engine of claim 4, since the sufficient self-locking force is obtained which corresponds to the strength of the cam torque even when the cam torque in the advance direction is stronger than the cam torque in the lag direction, the misalignment of the relative phase angle of the cam shaft with respect to the drive rotating member can be securely prevented.

[0029] In accordance with the variable phaser for the automobile engine of claim 5, the strength of the self-locking force can be adjusted in correspondence with the strength of the cam torque by replacing the pressure receiving section based on the strength of the cam torque.

Brief Description of Drawings

[0030]

[Fig.7.] A broken perspective view of a variable phaser of an automobile engine of a first Example viewed from the front of the phaser.

[Fig.2] A broken perspective view of the variable phaser of the automobile engine of the first Example viewed from the rear of the phaser.

[Fig.3] A front elevational view of the variable phaser of the automobile engine of the first Example.

[Fig. 4] A cross-sectional view taken along a line A-A of Fig. 3.

[Fig.5] (a) A cross-sectional view taken along a line B-B of Fig.4. (b) A cross-sectional view taken along a line C-C of Fig.4. (c) A cross-sectional view taken along a line D-D of Fig.4.

[Fig.6] (a) A cross-sectional view taken along a line E-E of Fig.4. (b) A cross-sectional view taken along a line F-F of Fig.4.

[Fig.7] (a) An enlarged partial cross-sectional view of a first lock plate and a holding section of Fig.6(a). (b) An enlarged partial cross-sectional view of a second lock plate and the holding section of Fig.6(a). (c) An enlarged partial cross-sectional view of a third lock plate and the holding section of Fig.6(a).

[Fig.8] (a) A diagram of a self-lock mechanism when a cam torque in an advance direction (D1 direction) is generated in a cam shaft in the first Example (b) A diagram of a self-lock mechanism when a cam torque in a lag direction (D2 direction) is generated in a cam shaft.

[Fig.9] A broken perspective view of a variable phaser of an automobile engine of a second Example viewed from the front of the phaser.

[Fig.10] A cross-sectional view of the variable phaser for the automobile engine taken at a position corresponding to E-E of Fig.4, which shows a shape of a lock plate of the second Example.

[Fig.11] (a) An enlarged partial cross-sectional view of a first lock plate and a holding section of Fig.10, (b) An enlarged partial cross-sectional view of a second lock plate and the holding section of Fig.10.

[Fig 12] (a) A diagram of a self-lock mechanism when

a cam torque in an advance direction (D1 direction) is generated in a cam shaft in the second Example. (b) A diagram of a self-lock mechanism when a cam torque in a lag direction (D2 direction) is generated in a cam shaft.

[Fig.13] A broken perspective view of a variable phaser of an automobile engine of a third Example viewed from the front of the phaser..

[Fig.14] A broken perspective view of the variable phaser of the automobile engine of the third Example viewed from the rear of the phaser.

[Fig.15] A cross-sectional view of the variable phaser for the automobile engine taken at a position corresponding to E-E of Fig. 4, which shows a shape of a lock plate of the third Example.

[Fig 16] (a) An enlarged partial cross-sectional view of a first lock plate and a holding section of Fig. 15.

(b) An enlarged partial cross-sectional view of a second lock plate and the holding section of Fig.15. (c) An enlarged partial cross-sectional view of a third lock plate and the holding section of Fig.15.

Embodiments for Implementing Invention

[0031] Variable phasers of an automobile engine shown in the respective Examples are apparatuses which are mounted in the engine and transmits the rotations of a crank shaft to a cam shaft such that intake and exhaust valves are open or closed in synchronization with the rotation of the crank shaft, and further changes the opening-closing timing of the intake and exhaust valves of the engine depending on the driving conditions such as the load of the engine and the number of rotations.

[0032] A variable phaser 1 of an automobile engine of a first Example includes, as shown in Fig.1 to Fig 6, a drive rotating member 2 driven and rotated by a crank shaft, a first control rotating member 3, a cam shaft 6, a relative phase angle changing mechanism 10, and a self-locking mechanism 11.

[0033] The description proceeds in the respective drawings such that a second electromagnetic clutch side is a front side (direction of symbol Fr) of the apparatus and the drive rotating member side is a rear side (direction of symbol Fe) of the apparatus. Further, the description proceeds such that upper side : lower side : right side : left side = Up, Dw, Le, Ri. With regard to the rotating direction of the drive rotating member 2 rotating around a central shaft line L0 of the cam shaft, a clockwise direction viewed from the front of the apparatus is defined as an advance direction (direction of symbol D1), and an anti-clockwise direction is defined as a lag direction (direction of symbol D2) for the present description.

[0034] As shown in Fig.1 and Fig.2, the drive rotating member 2 includes a sprocket 4 and a drive cylinder 5 which receive a driving force from the crank shaft The sprocket 4 has a central circular aperture 4a and a plurality of uneven penetration apertures 4b. The rotating cylinder 5 has a bottomed cylindrical shape including a

bottom 5c and a cylindrical section 20. As shown in Fig. 1 and Fig. 6(b), a central circular aperture 5a, a plurality of female screw apertures 5b, a fixation aperture 5d and bottomed circumferential-direction extending trenches 5e in the bottom 5c are formed. A thick round shaft 32a of an shaft-shaped element 32 composed of the thick round shaft 32a and a thin round shaft 32b is inserted into the fixation aperture 5d and fixed. The sprocket 4 and the drive cylinder 5 are integrated by inserting a plurality of bolts 2a through the uneven penetration apertures 4b and threadably mounting to the female screw apertures 5b.

[0035] As shown in Fig. 1, Fig. 2, Fig. 4 and Fig. 5(c), the first control rotating member 3 is formed by a cylindrical section 3b having a flange section 3a at its front end, and a bottom section 3c continuously formed from the cylindrical section 3b along a rear direction. A central penetration circular aperture 3d, a pair of first pin apertures 28, a circumferential-direction extending trench 30 formed on a circle having a specified radius around the central shaft line L0, and a curved first size-decreasing guide trench 31 in which a distance from the central shaft line L0 to the guide trench decreases along the lag direction D1 are formed in the bottom section 3c.

[0036] As shown in Fig. 1, Fig. 2 and Fig. 4, a center shaft 7 includes a first cylindrical section 7a continuously extending along the central shaft line L0 in a front-back direction, a flange section 7b, a second cylindrical section 7c, and a third cylindrical section 7d. A flange-shaped holding section 12 of the lock plate is formed around the base of the third cylindrical section 3d, and a circular aperture 7e is formed at the center of the center shaft 7. As shown in Fig. 4, the cam shaft 6 having the cam 6b is integrated with the rear end of the center shaft 7 in a coaxial and relative rotation disabling fashion by inserting a bolt 37 into the circular aperture 7e and a female screw aperture 6a which is open toward the front of the cam shaft 6.

[0037] As shown in Fig. 1 and Fig. 6(a), the outer circumferential surface of the holding section 12 is formed by six surfaces in a shape of regular hexagon having the central shaft line L0 at its center. The six outer circumferential surfaces of the holding section 12 act as plate-pressing surfaces (12a to 12c) every other surface, and the plate-pressing surfaces (12a to 12c) are disposed at a plurality of positions almost equally separated along an outer circumferential direction of the cam shaft.

[0038] As shown in Fig. 2 and Fig. 4, the drive rotating member 2 is formed by integrating the sprocket 4 formed by inserting the first cylindrical section 7a into the circular aperture 4a, and the drive cylinder 5 formed by inserting the second cylindrical section 7c into the circular aperture 5a, by using the bolts 2a. As a result, the drive rotating member 2 is rotatably supported around the center shaft. The third cylindrical section 7d is inserted into the central circular aperture 3d of the first control rotating member 3. The drive rotating member 2, the first control rotating member 3, the cam shaft 6 and the center shaft

7 are disposed coaxially around the central shaft line L0.

[0039] The relative phase angle changing mechanism 10 shown in Fig. 1, Fig. 2 and Fig. 4 is a mechanism in which the cam shaft 6 is relatively rotated along either of the advance direction D1 or the lag direction D2 with respect to drive rotating member 2 which interlocks with the rotation of the crank shaft. The relative phase angle changing mechanism 10 is configured by the first control rotating member 3, the center shaft 7 integrated with the cam shaft 6, the self-locking mechanism 11, and a connecting mechanism 16, a first electromagnetic clutch 21 which relatively rotates the first control rotating member 3 with respect to the drive rotating member 2 by means of braking the first control rotating member 3, and a reverse rotating mechanism 22 which relatively rotates the first control rotating member 3, with respect to the drive rotating member 2, in a direction reverse to that at the actuation of the first electromagnetic clutch 21.

[0040] The self-locking mechanism 11, which is arranged between the drive rotating member 2 and the center shaft 7, is a mechanism for preventing occurrence of the misalignment of the mounting angle of the cam shaft 6 with respect to the drive rotating member 2 caused by the cam torque which is received by the cam shaft 6 from a valve spring not shown in the drawings. The self-locking mechanism 11 is configured by the holding section 12 of the center shaft 12, the lock plate 14 and the cylindrical section 20 of the drive rotating member 2.

[0041] The lock plates 14 are mounted the same number as the plate-pressing surfaces (12a to 12c) of the holding section 12. As shown in Fig. 1, Fig. 2 and Fig. 6(a), the lock plate 14 is formed by a first lock plate 14a, a second lock plate 14b and a third lock plate 14c by equally dividing the circular plate having a nearly triangle-shaped penetration aperture 14d on its center into three parts which coincide with the number of the plate-pressing surfaces (12a to 12c). Inside of the first to third lock plates (14a to 14c), pressure receiving sections (15a to 15c) formed by surfaces parallel to plate-pressing surfaces (12a to 12c) are formed at the positions corresponding to the plate-pressing surfaces (12a to 12c).

[0042] As shown in Fig. 1, Fig. 2 and Fig. 6(a), a circumferential-direction extending trench 14h which penetrates in a front-back direction at a position corresponding to the circumferential-direction extending trench 30 is formed in the first lock plate 14a. Pin apertures 14i are formed in the second and third lock plates (14b, 14c) at the positions corresponding to the pair of pin apertures 28 of the first control rotating member 3.

[0043] As shown in Figs. 7(a) to (c), the plate-pressing surface 12a of the holding section 12 is formed by first and second pressing surfaces (13a, 13b), the pressing surface 12b is formed by first and second pressing surfaces (13c, 13d), and the pressing surface 12c is formed by first and second pressing surfaces (13e, 13f). When virtual surfaces (S1 to S3) perpendicular to the plate-pressing surfaces (12a to 12c) at the intersection lines (C1 to C3) are presumed, the first and the second press-

ing surfaces (13a, 13b), (13c, 13d), (13e, 13f) are divided into the respective two regions on each of the plate-pressing surfaces (12a to 12c) separated by the virtual surfaces (S1 to S3).

[0044] As shown in Fig.6 (a) and Figs.7 (a) to (c), first and second acting sections (17a, 17b), (17c, 17d), (17e, 17f) processed to minute arc shapes are arranged at the respective ends of the pressure receiving sections (15a to 15c). The first acting sections (17a, 17b, 17c) are arranged at positions corresponding to the first pressing surfaces (13a, 13b, 13c), and, as shown in Fig.8(a), receive a self-locking force F by the cam torque in the advance direction, in contact with the first pressing surface 13a (refer to Fig.8(a)). The second acting sections (17b, 17d, 17f) are arranged at positions corresponding to the second pressing surfaces (13b, 13d, 13f), and, as shown in Fig 8(b), receive a self-locking force F by the cam torque in the lag direction (D2 direction) in contact with the second pressing surface 13b. As shown in Figs. 7 (a) to (c), the first and the second acting sections (17a, 17b) are formed on the pressure receiving sections (12a to 12c) such that a second distance d2 from the virtual surface S1 to the second acting section 17b is shorter than a first distance d1 from the virtual surface S1 to the first acting section 17a.

[0045] As shown in Fig.6 (a), the lock plates (14a to 14c) are held on the holding section 12 by contacting the pressure receiving sections (15a to 15c) onto the plate-pressing surfaces (12a to 12c). The outer circumferential surfaces (14e to 14g) of the lock plate (14a to 14c) are internally contacted with the inner circumferential surface 20a of the cylindrical section 20 of the drive cylinder 5.

[0046] As shown in Fig.6(a), the thick round shaft 32a of the shaft-shaped element 32 fixed to the drive cylinder 5 is inserted into the circumferential-direction extending trench 14h of the first lock plate 14a. The connecting mechanism 16 is formed by a pair of connecting pins (27, 27), the pair of the first pin apertures (28, 28) formed on the bottom section 3b of the control rotating member 3, and a pair of second pin apertures (14i, 14j) formed in the second and third lock plates (14b, 14c), respectively. The pair of the connecting pins (27, 27) inserted into the second pin apertures (14i, 14j) from the rear side are fixed to the second and third lock plates (14b, 14c). As shown in Fig.6(b), the rear end of the connecting pin 27 is inserted into the circumferential-direction extending trench 5e of the drive cylinder 5. The first control rotating member is connected to the second and the third lock plates (14b, 14c) by inserting the front ends of the pair of the connecting pins 27 into the first pin apertures 28 shown in Fig.5(c).

[0047] As shown in Fig.6(a), a circular cylinder-shaped pin 33 is disposed between the first lock plate 14a and the second lock plate 14b, and a circular cylinder-shaped pin 34 is disposed between the first lock plate 14a and the third lock plate 14c. A helical compression spring 35 which biases the second lock plate 14b along a direction so as to be departed from the third lock plate 14c is dis-

posed between the second lock plate 14b and the third lock plate 14c. The first lock plate receives the biasing force of the helical compression spring 35 via the pins (33, 34) in contact with the second and the third lock plates (14b, 14c). As a result, the first to the third lock plates (14a to 14c) are tightly in contact with the inner circumferential surface 20a of the cylindrical section 20.

[0048] As shown in Fig.1, Fig. 2 and Fig.4, a first electromagnetic clutch 21 which is fixed on a covering member 36 fixed in the interior of the engine not shown in the drawings is positioned in a forward direction of the first control rotating member 3. The first electromagnetic clutch 21 during the working sucks a front surface 3e of the flange section 3a of the first control rotating member 3 and brings into contact with a friction material 21a. A reverse rotating mechanism 22 is configured by the first size-decreasing guide trench 31 of the first control rotating member 3, the shaft-shaped element 32, a second electromagnetic clutch 38, the second control rotating member 39, the size-decreasing guide trench 40 of the second control rotating member 39, a crank member 41 and first and second pin mechanisms (42, 43).

[0049] As shown in Fig.1, Fig. 2 and Fig.5(a), the second control rotating member 39 is disc-shaped and includes a central penetration circular aperture 39a and the size-decreasing guide trench 40. The second control rotating member 39 is rotatably supported by a third cylindrical section 7d of the center shaft 7 via the penetration circular aperture 39a. The second size-decreasing guide trench 40 is a bottomed trench open toward a rear direction, and further is a curved trench in which a distance from the central shaft line L0 to the second size-decreasing guide trench 40 decreases toward the lag D2 direction. As shown in Fig 4, front surfaces (3e, 39b) of the first and the second control rotating members (3, 39) are disposed to be aligned with each other, and the first and the second control rotating members (3, 39) are retained toward the front direction by a holder equipped to a bolt 37. The second electromagnetic clutch 38 is disposed in front of the second control rotating member 39 inside of the first electromagnetic clutch 21. The second electromagnetic clutch 38 during the working sucks the front surface 39b of the second control rotating member 39 and brings into contact with a friction material 38a.

[0050] As shown in Fig. 1 and Fig. 5 (b), the crank member 41 disposed in the front direction of the first control rotating member 3 includes a ring main body 45 having thickness thicker toward a radius direction, a projecting section 46 projecting toward the outside of the radius direction from the ring main body 45, and a notch section 47 formed by removing part of an outer circumference of the ring main body 45 to make a thinner section. The notch section 47 is formed from the projecting section 46 to the region in the advance direction (D1 direction). A pin aperture 48 penetrating in the front-back direction is formed in the projecting section 46. First and second pin apertures (49, 50) penetrating in the front-back direction are formed in the ring main body 45. The first and the

second pin apertures (49, 50) are formed from the projecting section to the region in the lag D2 direction (D2 direction) in Fig.5(b)

[0051] As shown in Fig.1, Fig.5(c) and Fig.6(a), the thin round shaft 32b of the shaft-shaped element 32 fixed to the fixation aperture 5d of the drive cylinder 5 projects toward the front direction from the circumferential-direction extending trench 14h of the first lock plate 14a and from the circumferential-direction extending trench 30 of the first control rotating member 3, and is engaged with the pin aperture 48 of the crank member 41. As its result, the crank member 41 is rotatably supported by the thin round shaft 32b fixed to the drive cylinder 5.

[0052] As shown in Fig.1 and Fig.2, the first pin mechanism 42 is configured of a shaft-shaped member 42a and a first hollow oblong shaft 42b. The shaft-shaped member 42a is fixed to a pin aperture 49 of the crank member 41 via a small-sized member 42c from the rear, and the first hollow oblong shaft 42b is rotatably supported by the shaft-shaped member 42a at the rear of the crank member 41. A second pin mechanism 43 is configured of a shaft-shaped member 43a and a second hollow oblong shaft 43b. The shaft-shaped member 43a is fixed to a pin aperture 50 of the crank member 41 via a small-sized member 43c from the front, and the second hollow oblong shaft 43b is rotatably supported by the shaft-shaped member 43a at the front of the crank member 41. The first hollow oblong shaft 42b is engaged with the first size-decreasing guide trench 31, and is held along the first size-decreasing guide trench 31 in a displaceable manner. The second hollow oblong shaft 43b is engaged with the second size-decreasing guide trench 40, and is held along the second size-decreasing guide trench 40 in a displaceable manner.

[0053] At this stage, an operation of changing the relative phase angle of the center shaft 7 (cam shaft 6) with respect to the drive rotating member 2 will be described. When the first and the second electromagnetic clutches (21, 38) do not work, the first and the second control rotating members (3, 39) rotate along the D1 direction together with the drive rotating member 2 driven by a crank shaft (not shown). The cam shaft 6 is connected to the first control rotating member 3 via the lock plate 14 held on the holding section 12 of the center shaft 7. Accordingly, also the cam shaft 6 (refer to Fig.4) connected to the first control rotating member 3 rotates along the D1 direction together with the drive rotating member

[0054] When the relative phase angle of the center shaft 7 (cam shaft 6) with respect to the drive rotating member 2 is changed to the lag D2 direction, the first electromagnetic clutch 21 is actuated. The control rotating member 3 sucked by the first electromagnetic clutch 21 is braked by means of the contact with the friction material 21a, and a rotation delay along the D2 direction is produced with respect to the drive rotating member 3 together with the center shaft 7 (cam shaft 6). As a result, the relative phase angle of the center shaft 7 (cam shaft 6) with respect to the drive rotating member 2 (crank

shaft) is changed along the lag D2 direction, and the opening-closing timing of the engine valve not shown in the drawings is changed.

[0055] At this stage, as shown in Figs.5(b) and (c), the first hollow oblong shaft 42b supported by the shaft-shaped member 42a moves along the D3 direction in a nearly clockwise fashion in the first size-decreasing guide trench 14 guided by the first size-decreasing guide trench 31. At this stage, the crank member 41 rotates around the shaft-shaped member 32 along the D2 direction in an anti-clockwise fashion because the shaft-shaped member 42a connected to the first pin aperture 49 moves toward the inner side in the radius direction of the first control rotating member 3 along the first size-decreasing guide trench 31. When, on the other hand, the shaft-shaped member 43a connected to the second pin aperture 50 moves by means of the crank member 41, the second hollow oblong shaft 43b provides an inward force along the radius direction onto the inner circumferential surface of the second size-decreasing guide trench 40 by the movement along a D4 direction in a nearly anti-clockwise fashion in the second size-decreasing guide trench 40. As a result, the second control rotating member 39 relatively rotates along the advance D1 direction with respect to the center shaft 7.

[0056] When, on the other hand, the relative phase angle of the center shaft 7 (cam shaft 6) with respect to the drive rotating member 2 is changed to the advance D1 direction, the second electromagnetic clutch 38 is actuated. The second control rotating member 39 sucked by the second electromagnetic clutch 38 is braked by means of the contact with the friction material 38a.

[0057] As shown in Fig.5(a), the second control rotating member 39 braked by the second electromagnetic clutch 38 produces a rotation delay along the lag D2 direction with respect to the center shaft 7. The second hollow oblong shaft 43b moves along a D5 direction in a nearly clockwise fashion in the second size-decreasing guide trench 40 on receipt of a force from the inner circumference surface of the second size-decreasing guide trench 40, and the shaft-shaped member 42a connected to the crank member 41 moves toward the outer side along the radius direction of the first control rotating member 3. At this stage, the first hollow oblong shaft 39 shown in Fig.5(c) moves along a D6 direction in a nearly anti-clockwise fashion in the first size-decreasing guide trench 31, and provides an outward force along the radius direction onto the inner circumferential surface of the first size-decreasing guide trench 31. As a result, the first control rotating member 3 and the center shaft 7 relatively rotate in the advance D1 direction with respect to the drive rotating member 2. As a result, the relative phase angle of the center shaft 7 (cam shaft 6) with respect to the drive rotating member 2 (crank shaft) is returned along the advance D1 direction, and the opening-closing timing of the engine not shown in the drawings is changed again.

[0058] When the first control rotating member 3 and

the center shaft 7 relatively rotate with respect to the drive rotating member 2, the shaft-shaped member 32 displaces in the circumferential-direction extending trench 30, and the connecting pin 27 displaces in the circumferential-direction extending trench 5e. The both ends (5e1, 5e2) of the circumferential-direction extending trench 5e act as stoppers for disabling further relative rotation of the first control rotating member 3 and the center shaft 7 with respect to the drive rotating member 2, by contacting the connecting pins 27 to the both ends.

[0059] Then, the self-locking mechanism 11 will be described. A cam torque by a valve spring (not shown in the drawings) is alternately input in the advance D1 direction and the lag D2 direction onto the cam shaft 6 rotating together with the drive rotating member 2. The cam torque may derange the opening-closing timing of the valve by means of generating the misalignment of the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2 at the time of stopping the first and the second electromagnetic clutches (21, 39). The self-locking mechanism 11 prevents the misalignment of the above relative phase angle by means of the self-locking effects which hold the center shaft 7 having the holding section 12 unrotatably with respect to the drive rotating member 2 by pressing the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c) at the time of generating the cam torque on the inner circumferential surface 20a of the cylindrical section 20 of the drive cylinder 5.

[0060] Fig.8 (a) shows the self-locking effects when the cam torque is generated along the advance D1 direction in the cam shaft 6 (center shaft 7). When the center shaft 7 connected to the cam shaft receives the cam torque in the advance D1 direction, the holding section 12 having a regular hexagonal section tries to rotate along the D1 direction. At this stage, the first acting sections (17a, 17c, 17e) of the first to the third lock plates (14a to 14c) receive a self-locking force F in a direction perpendicular to the central shaft line L0 of the cam shaft from the first pressing surfaces (13a, 13c, 13e) of the plate-pressing surfaces (12a to 1c).

[0061] In Fig 8(a), when virtual surfaces passing through the first acting sections (17a, 17c, 17e) and parallel to the virtual sections (S1 to S3) are presumed to be (S4 to S6), and intersection lines between the virtual surfaces (S4 to S6) and the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c) are presumed to be (P1 to P3), the inner circumferential surfaces 20a of the cylindrical section 20 receives a force F at the intersection lines (P1 to P3) from the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c). The force F produces a friction force between the inner circumferential surfaces 20a of the cylindrical section 20 and the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c).

[0062] The above friction force is expressed as follows. In Fig.8(a), linear lines passing through the intersection

lines (P1 to P3) and extending to the tangential direction of the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c) are presumed to be L1, linear lines perpendicular to the virtual surfaces (S4 to S6) are presumed to be L2, linear lines perpendicular to the linear lines L1 are presumed to be L3, a slope between L3 and the virtual surfaces (S4 to S6) is presumed to be $\theta 1$ (hereinafter, $\theta 1$ is referred to as friction angle), and a friction coefficient of the friction surface is presumed to be μ . The force producing the misalignment of the relative phase angle of the center shaft (cam shaft 6) with respect to the drive rotating member 3 by the cam torque is expressed as a force $F \cdot \sin \theta 1$ in a tangential direction of the outer circumferential surfaces (14e to 14g) at the intersection lines (P1 to P3). On the other hand, the friction forces generated between the inner circumferential surface 20a of the cylindrical section 20 and the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c) are expressed as $\mu \cdot F \cdot \cos \theta 1$.

[0063] When the above friction force is larger than the force producing the misalignment in the relative phase angle, or the condition of $F \cdot \sin \theta 1 < \mu \cdot F \cdot \cos \theta 1$ is satisfied, the first to the third lock plates (14a to 14c) cannot relatively rotate with respect of the inner circumferential surface 20a of the cylindrical section 20 due to the friction force based on the self-locking force F. Accordingly, when the friction angle $\theta 1$ is established such that $\theta 1 < \tan^{-1} \mu$ is satisfied, the center shaft 7 (cam shaft 6) holding the first, to the third lock plates (14a to 14c) via the holding section 12 is held unrotatably with respect to the drive rotating member 2 having the cylindrical section 20.

[0064] On the other hand, Fig.8(b) shows the self-locking effects when the cam torque is generated along the lag D2 direction in the cam shaft 6 (center shaft 7) When the center shaft 7 receives the cam torque in the D2 direction, the holding section 12 having a regular hexagonal section tries to rotate along the D2 direction. At this stage, the second acting sections (17b, 17d, 17f) of the first to the third lock plates (14a to 14c) receive a self-locking force F in a direction perpendicular to the central shaft line L0 of the cam shaft from the second pressing surfaces (13b, 13d, 13f) of the plate-pressing surfaces (12a to 12c).

[0065] As shown in Fig.8(b), when virtual surfaces passing through the second acting sections (17b, 17d, 17f) and parallel to the virtual sections (S1 to S3) are presumed to be (S7 to S9), and intersection lines between the virtual surfaces (S7 to S9) and the first to the third lock plates (14a to 14c) are presumed to be (P4 to P7), the inner circumferential surfaces 20a of the cylindrical section 20 receives a force F at the intersection lines (P4 to P7) from the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c). The force F produces a friction force as specified below between the inner circumferential surfaces 20a of the cylindrical section 20 and the outer circumferential surfaces (14e to 14g) of the first to the third lock plates

(14a to 14c).

[0066] In Fig. 8(b), linear lines passing through the intersection lines (P4 to P6) and extending to the tangential direction of the outer circumferential surfaces (14e to 14g) are presumed to be L4, linear lines perpendicular to the virtual surfaces (S7 to S9) are presumed to be L5, linear lines perpendicular to the linear lines L4 are presumed to be L6, and a slope between L6 and the virtual surfaces (S7 to S9) is presumed to be θ_2 (hereinafter, θ_2 is referred to as friction angle). The force producing the misalignment of the relative phase angle of the center shaft (cam shaft 6) with respect to the drive rotating member 2 by the cam torque is expressed as a force $F \cdot \sin \theta_2$ in a tangential direction of the outer circumferential surfaces (14e to 14g) at the intersection lines (P4 to P6). On the other hand, the friction forces generated between the inner circumferential surface 20a of the cylindrical section 20 and the outer circumferential surfaces (14e to 14g) of the first to the third lock plates (14a to 14c) are expressed as $\mu \cdot F \cdot \cos \theta_2$.

[0067] When the condition of $F \cdot \sin \theta_2 < \mu \cdot F \cdot \cos \theta_2$ is satisfied, the first to the third lock plates (14a to 14c) cannot relatively rotate with respect of the inner circumferential surface 20a of the cylindrical section 20. Accordingly, when the friction angle θ_2 is established such that $\theta_2 < \tan^{-1} \mu$ is satisfied, the center shaft 7 (cam shaft 6) is held unrotatably with respect to the drive rotating member 2 (crank shaft not shown in the drawings).

[0068] As shown in Figs. 8(a) and (b), even if the cam torque is generated in the cam shaft 6 in either of the advance D1 direction or the lag D2 direction in the self-locking mechanism 11, the self-locking effects are produced such that the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2 (crank shaft not shown in the drawings) is held without the misalignment.

[0069] As shown in Figs. 8(a) and (b), the self-locking functions are created in all of the first to the third lock plates (14a to 14c) by means of the self-locking mechanism 11 when the cam torque along either of the D1 direction or the D2 direction is received. The first to the third lock plates (14a to 14c) are arranged at a plurality of positions equally separated along a circumferential direction of the inner circumferential surface 20a of the cylindrical section 20. Accordingly, the uniform self-locking effects are created on all of the inner circumferential surface of the cylindrical section 20 of the drive rotating member 5 by the uniform force F . When the uniform self-locking effects are created on all of the circumferential surface, the lock plates 14 do not dig into the inner circumferential surface 20a of the cylindrical section 20, and the drive rotating member 2 does not slant with respect to the central shaft line L0 of the cam shaft. Accordingly, in case of changing the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2, no superfluous friction force is generated between the lock plates 14 and the cylindrical section 20, and no superfluous friction force is generated also between the

drive rotating member 5 and the center shaft 7 holding the drive rotating member 5. As a result, the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2 (crank shaft not shown in the drawings) is smoothly changed without any influence of the self-locking mechanism 11 during the working of the first or the second electromagnetic clutch (21, 39).

[0070] The cam torque generated in the cam shaft 6 along the lag D2 direction which is generated by an elastic force the cam receives from a valve spring when the cam pushes down the engine valve is larger than the cam torque generated along the advance D1 direction. Accordingly, the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2 is likely to generate more misalignment in the D2 direction than in the D1 direction when the cam torque is received so that it is desirable that the self-locking effects by the cam torque in the D2 direction is produced more remarkable than the self-locking effects by the cam torque in the D1 direction in the self-locking mechanism 11.

[0071] As shown in Figs. 7(a) to (c), a second distance d_2 from the second acting sections (17b, 17d, 17f) of the pressure receiving sections (15a to 15c) to the virtual surfaces (S1 to S3) is shorter than a first distance d_1 from the first acting sections (17a, 17c, 17e) to the virtual surfaces (S1 to S3). Accordingly, $\theta_1 > \theta_2$ is satisfied in the self-locking mechanism 11 shown in Figs. 8 (a) and (b). In this case, the friction force ($\mu \cdot F \cdot \cos \theta_2$) by the cam torque along the lag D2 direction is larger than the friction force ($\mu \cdot F \cdot \cos \theta_1$) by the cam torque along the advance D1 direction. Accordingly, the self-locking effects by the cam torque along the D2 direction is larger than the self-locking effects by the cam torque along the D1 direction so that the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2 is held without misalignment even if the cam torque is received.

[0072] Then, a second Example of the variable phaser for the automobile engine will be described referring to Fig. 9 to Fig. 12. The variable phaser 55 for the automobile engine of the second Example possesses the same configuration as those of the variable phaser 1 for the automobile engine of the first Example except that a holding section 57 and lock plates 58 are different from the holding section 12 and the lock plates 14 of the first Example, and the pins (33, 34) are not mounted.

[0073] A center shaft 56 possesses the common shape as that of the center shaft 7 of the first Example except that the holding section 57 includes a different shape. The center shaft 56 is configured by continuously forming a first cylindrical section 56a, a flange section 56b, a second cylindrical section 56c, the holding section 57 of the lock plate 58, and a third cylindrical section 57d along a central shaft line L0 in a front-back direction. The holding section 57 is formed in a flange-shaped fashion around the base of the third cylindrical section 57d.

[0074] As shown in Fig. 10, the outer circumferential surface of the holding section 57 includes a sectional shape formed by cutting out, in parallel to the central

shaft line L0 of the cam shaft, two parts of the outer circumference 2 of a cylinder having the central shaft line L0 of the cam shaft as its center. The cut-out parts of the holding section 57 includes a symmetrical shape extending on the both sides of the central shaft line L0 and forms two plate pressing surfaces (57a, 57b) in parallel to each other.

[0075] As shown in Fig. 9, the drive rotating member 2 is configured by integrating, by means of a bolt 2a, a sprocket 4 formed by inserting the first cylindrical section 56a into a circular aperture 4a, and a drive cylinder 5 formed by inserting the second cylindrical section 56c into a circular aperture 5a. The drive rotating member 2 is rotatably supported around the center shaft 56..

[0076] As shown in Fig 10, the lock plate 58 is mounted of which the number is the same as that of the plate-pressing surfaces (57a, 57b) of the holding section 57. The lock plate 58 is formed by a first lock plate 58a and a second lock plate 58b which are obtained by bisecting a circular plate having a penetration trench 59 at its center extending along a diameter direction. Pressure receiving sections (59a, 59b) having surfaces in parallel to the plate-pressing surfaces (57a, 57b) are mounted at positions corresponding to the plate-pressing surfaces (57a, 57b), respectively, and on the inside of the first and the second lock plates (58a, 58b).

[0077] As shown in Figs.11(a) (b), the plate-pressing surface 57a of the holding sections 57 are configured by the first and the second pressing surfaces (60a, 60b), and the plate-pressing surfaces 57b is configured by the first and the second pressing surfaces (60c, 60d). When a virtual surface (S10) perpendicular to the plate-pressing surfaces (57a, 57b) at the intersection lines (C4, C5) is presumed, the first and the second pressing surfaces (60a, 60b) and (60c, 60d) are divided into the respective two regions on each of the plate-pressing surfaces (57a, 57b) separated by the virtual surface (S10)

[0078] As shown in Figs. 11 (a) (b), first and second acting sections (61a, 61b) processed to minute arc shapes and in contact with the first and the second pressing surfaces (60a, 60b) are arranged at the ends of the pressure receiving section 59a, and first and second acting sections (61c, 61d) processed to minute arc shapes and in contact with the first and the second pressing surfaces (60c, 60d) are arranged at the ends of the pressure receiving section 59b. The first and the second acting sections (61a, 62b) and (61c, 61d) are formed at the pressure receiving sections (59a, 59b), respectively, such that a second distance d4 from the virtual surface S10 to the second acting sections (61b, 61d) is shorter than a first distance d3 from the virtual surface S10 to the first acting sections (61a, 61c). The first acting sections (61a, 61c) receive a self-locking force F1 due to the cam torque along the advance direction (D1 direction) from the first pressing surfaces (60a, 60c) (refer to Fig. 11(a)). The second acting sections (61b, 61d) receive a self-locking force F1 due to the cam torque along the lag direction (D2 direction) from the second pressing surfaces (60b, 60d)

(refer to Fig.11(a)). As shown in Fig.9 and Fig.10, a pair of second pin apertures are formed at positions of the first and the second lock plates (58a, 58b) corresponding to the pair of the first pin apertures 28 of the first control rotating member 3 shown in Fig.1.

[0079] As shown in Fig.10, the first and the second lock plates (58a, 58b) are held on the holding section 57. The outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) are internally contacted with the inner circumferential surface 20a of the cylindrical section 20 of the drive cylinder 5.

[0080] Further, as shown in Fig.10, a compression coil spring 62 is placed in a space between the first lock plate 58a and the second lock plate 58b, and the first lock plate 58a receives, from the compression coil spring 62, a biasing force in a direction separated from the second lock plate 58b. As a result, the first and the second lock plates (58a, 58b) are tightly in contact with the inner circumferential surface 20a of the cylindrical section 20 without any space.

[0081] On the other hand, as shown in Fig 9 and Fig.10, the first and the second lock plates (58a, 58b) are connected to and rotate with the first control rotating member 3 by means of inserting the front ends of the pair of the connecting pins 27 each of which are fixed to the pair of the second pin apertures 58c into the corresponding first pin apertures 28. The rear ends of the connecting pins are inserted into the circumferential-direction extending trenches 5e of the drive cylinder 5.

[0082] Then, the self-locking mechanism 65 of the variable phaser 55 for the automobile engine of the second Example will be described referring to Fig. 11 and Fig. 12, The self-locking mechanism 65 is configured by the holding section 57 of the center shaft 56, the lock plate 58, and the cylindrical section 20 of the drive cylinder 5 of the drive rotating member 2.

[0083] As shown in Fig.12(a), when the cam shaft coaxially integrated with the center shaft. 56 (similar to the cam shaft 6 of Fig.1) receives the cam torque in the advance D1 direction from the engine valve, the holding section 57 tries to rotate along the D1 direction. At this stage, the first acting sections (61a, 61c) of the first and the second lock plates (58a, 58b) receive the self-locking force F1 in a direction perpendicular to the central shaft line L0 of the cam shaft from the first pressing surfaces (60a, 60c) of the plate pressing surfaces (57a, 57b).

[0084] In Fig.12(a), when virtual surfaces passing through the first acting sections (61a, 61c) and parallel to the virtual surface S10 are presumed to be (S11, S12), and intersection lines between the virtual surfaces (S11, S12) and the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) are presumed to be (P7, P8), the inner circumferential surfaces 20a of the cylindrical section 20 receive a force F1 at the intersection lines (P7, P8) from the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) The force F1 produces a friction force between the inner circumferential surfaces 20a of

the cylindrical section 20 and the outer circumferential surfaces (58d, 58e)

[0085] The above friction force is expressed as follows. At first, in Fig.12(a), each of linear lines passing through the intersection lines (P7, P8) and extending to the tangential direction of the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) are presumed to be L7, each of linear lines perpendicular to the virtual surfaces (S11, S12) are presumed to be L8, each of linear lines perpendicular to the linear lines L7 are presumed to be L9, each of slopes between L9 and the virtual surfaces (S11, S12) are presumed to be θ_3 (hereinafter, θ_3 is referred to as friction angle), and a friction coefficient of the friction surface is presumed to be μ . The force producing the misalignment of the relative phase angle of the center shaft 56 with respect to the drive rotating member 2 by the cam torque is expressed as a force $F \cdot \sin \theta_3$ in a tangential direction of the outer circumferential surfaces (58d, 58e) at the intersection lines (P7, P8). On the other hand, each of the friction forces generated between the inner circumferential surface 20a of the cylindrical section 20 and the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) are expressed as $\mu \cdot F_1 \cdot \cos \theta_3$.

[0086] When the condition of $F_1 \cdot \sin \theta_3 < \mu \cdot F_1 \cdot \cos \theta_3$ is satisfied, the first and the second lock plates (58a, 58b) cannot relatively rotate with respect of the inner circumferential surface 20a of the cylindrical section 20 due to the self-locking effects based on the friction force. Accordingly, when the friction angle θ_3 is established such that $\theta_3 < \tan^{-1} \mu$ is satisfied, the center shaft 56 (cam shaft not shown in the drawings) holding the first and the second lock plates (58a, 58b) via the holding section 57 is held unrotatably with respect to the drive rotating member 2 having the cylindrical section 20, and the relative phase angle of the center shaft (cam shaft not shown in the drawings) with respect to the drive rotating member 2 (crank shaft not shown in the drawings) is held without misalignment by the cam torque

[0087] As shown in Fig. 12 (b), when the cam shaft not shown in the drawings receives the cam torque in the lag D2 direction from the engine valve, the holding section 57 tries to rotate along the D2 direction. At this stage, the second acting sections (61b, 61d) of the first and the second lock plates (58a, 58b) shown in Figs.11(a)(b) receive the self-locking force F1 in a direction perpendicular to the central shaft line L0 of the cam shaft from the second pressing surfaces (60b, 60d) of the plate-pressing surfaces (57a, 57b)

[0088] In Fig.12(b), when each of virtual surfaces passing through the second acting sections (61b, 61d) and parallel to the virtual surface S10 are presumed to be (S13, S14), and each of intersection lines between the virtual surfaces (S13, S14) and the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) are presumed to be (P9, P10), the inner circumferential surfaces 20a of the cylindrical section 20 receive a force F1 at the intersection lines (P9, P10) from

the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b). The force F1 produces a friction force between the inner circumferential surfaces 20a of the cylindrical section 20 and the outer circumferential surfaces (58d, 58e).

[0089] The above friction force is expressed as follows. At first, in Fig.12(b), each of linear lines passing through the intersection lines (P9, P10) and (P7, P8) and extending to the tangential direction of the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) are presumed to be L10, each of linear lines perpendicular to the virtual surface S10 is presumed to be L11, each of linear lines perpendicular to the linear lines L10 is presumed to be L12, a linear line perpendicular to the linear line L10 is presumed to be L12, and a slope between L12 and the virtual surface S10 is presumed to be θ_4 (hereinafter, θ_4 is referred to as friction angle). The force producing the misalignment of the relative phase angle of the center shaft 56 with respect to the drive rotating member 2 by the cam torque is expressed as a force $F_1 \cdot \sin \theta_4$ in a tangential direction of the outer circumferential surfaces (58d, 58e) at the intersection lines (P9, P10). On the other hand, each of the friction forces generated between the inner circumferential surface 20a of the cylindrical section 20 and the outer circumferential surfaces (58d, 58e) of the first and the second lock plates (58a, 58b) is expressed as $\mu \cdot F_1 \cdot \cos \theta_4$.

[0090] When the condition of $F_1 \cdot \sin \theta_4 < \mu \cdot F_1 \cdot \cos \theta_4$ is satisfied, the first and the second lock plates (58a, 58b) cannot relatively rotate with respect of the inner circumferential surface 20a of the cylindrical section 20 due to the self-locking effects based on the friction force. Accordingly, when the friction angle θ_4 is established such that $\theta_4 < \tan^{-1} \mu$ is satisfied, the relative phase angle of the center shaft (cam shaft not shown in the drawings) with respect to the drive rotating member 2 (crank shaft not shown in the drawings) is held without misalignment by the cam torque.

[0091] The self-locking functions are created by the self-locking mechanism 65 in both of the first and the second lock plates (58a, 58b) arranged at a plurality of positions equally separated along an outer circumferential direction in the inner circumferential surface 20a of the cylindrical section 20 when the cam torque along either of the D1 direction or the D2 direction is received. Accordingly, the uniform self-locking effects are created on the inner circumferential surface of the cylindrical section 20 of the drive rotating member 5 by the force F. Accordingly, the lock plates 58 do not dig into the inner circumferential surface 20a of the cylindrical section 20 at the time of the generation of the self-locking effects, and the drive rotating member 2 does not slant with respect to the central shaft line L0 of the cam shaft. Accordingly, in case of changing the relative phase angle of the cam shaft 6 with respect to the drive rotating member 2, no superfluous friction force is generated between the lock plates 58 and the cylindrical section 20, and no

superfluous friction force is generated also between the drive rotating member 5 and the center shaft 56 holding the drive rotating member 5. As a result, the relative phase angle of the cam shaft 56 (cam shaft not shown in the drawings) with respect to the drive rotating member 2 (crank shaft not shown in the drawings) is smoothly changed without any influence of the self-locking mechanism 6 5 during the working of the first or the second electromagnetic clutch (21, 38).

[0092] As shown in Figs. 11 (a) (b), the second distance d_4 from the second acting sections (61b, 61d) of the pressure-receiving sections (59a, 59b) to the virtual surface S10 is shorter than the first distance d_3 from the first acting sections (61a, 61c) to the virtual surface S10 so that $\theta_3 > \theta_4$ is satisfied in Figs. 11(a) (b). In this case, the friction forces ($\mu \cdot F_1 \cos \theta_4$) by the cam torque along the lag D2 direction is larger than the friction force ($\mu \cdot F_1 \cos \theta_3$) by the cam torque along the advance D1 direction. Accordingly, the self-locking effects by the cam torque along the D2 direction are larger than the self-locking effects by the cam torque along the D1 direction.. As a result, the relative phase angle of the cam shaft with respect to the drive rotating member 2 is held without misalignment even if the cam torque along the D2 direction is larger than the cam torque along the D1 direction.

[0093] Then, a third Example of the variable phaser for the automobile engine will be described referring to Fig. 13 to Fig. 16. In a variable phaser 70 for the automobile engine of the third Example, shapes of a first control rotating member 71, a drive cylinder 72 and a lock plate 73 are different from the first control rotating member 3, the drive cylinder 5 and the lock plate 14. In the variable phaser 70 for the automobile engine, the connecting pins 27 of the first Example, and connecting pins (74 to 76) in place of the pins (33, 34) are mounted.. The configuration of the third Example other than the above is common to the variable phaser 1 for the automobile engine of the first Example.

[0094] As shown in Figs. 13 and 14, the first control rotating member 71 is formed by a cylindrical section 71b having a flange section 71a at its front end, and a bottom section 71c continuously formed from the cylindrical section 71b along a rear direction. The first control rotating member 71 possesses the configuration common to that of the first control rotating member 3 of the first Example except that the shape of the bottom section 71c is different from the bottom section 3c shown in Fig. 1 and Fig. 5(c). That is, a central penetration circular aperture 71d, a circumferential-direction trench 77 and a first size-decreasing guide trench 78 are formed on the bottom section 71a, these shapes are same as the central penetration circular aperture 3d, the circumferential-direction extending trench 30 and the first size-decreasing guide trench 31 shown in Fig. 5(c). On the other hand, three pin fixation apertures 79 are formed in the bottom section 71a instead of the pair of the pin apertures 27 formed in the bottom section 3c. Thin rounded shafts (74b to 76d) of connecting pins (74 to 76) are equipped to the three

pin fixation apertures 79. The connecting pins (74 to 76) are formed by thick rounded shafts (74a to 76a) at the rear end and thin rounded shafts (74b to 76b) at the front end.

[0095] A drive cylinder 72 shown in Figs. 13 and 14 includes the common configuration as that of the drive cylinder 5 of the first example except that the former includes, in its bottom 72c, no bottomed circumferential-direction extending trenches 5e in the bottom 5c shown in Fig. 6(b). The drive cylinder 72 has a bottomed cylindrical shape formed by the bottom 72c and a cylindrical section 80, and includes a central circular aperture 72 for securing it to a second cylindrical section 7c of the center shaft 7, a plurality of female screw apertures 72b and a fixation aperture 72d in the bottom 72c. Similarly to the first example, the thick round shaft 32a of the shaft-shaped element 32 shown in Fig. 1 and Fig. 6(b) is inserted into and fixed to the fixation aperture 72d. The sprocket 4 and the drive cylinder 72 are integrated and configures a drive rotating member 2' by inserting the plurality of the bolts 2 into the plurality of the uneven penetration apertures 4b and threadably mounting on the female screw apertures 72b.

[0096] As shown in Fig. 15, a lock plate 73 is formed by a first lock plate 73a, a second lock plate 73b and a third lock plate 73c which are obtained by equally trisecting a rounded plate including a penetration aperture 73 of a nearly triangular shape at its center. As shown in Figs. 16 (a) to (c), mounting sections (73e to 73g) are equipped for freely attaching and detaching three pressure-receiving plates (81a to 81c) having the same shapes at the inner sides of the first to the third lock plates (73a to 73c). The pressure-receiving plates (81a to 81c) are fixed on the mounting sections (73e to 73g) by being pressed by the plate-pressing surfaces (12a to 12c) to the mounting sections (73e to 73g) under a situation being engaged to the mounting sections (73e to 73g). As shown in Fig 15, a circumferential-direction extending trench 73 penetrating the first lock plate 73a in an anteroposterior direction at a position corresponding to the circumferential-direction extending trench 77 of the first control rotating member 71 is formed.

[0097] As shown in Fig. 15, the plate-pressing surfaces (12a to 12c) of the holding section 12 are formed by the first and the second pressing surfaces (13a, 13b) (13c, 13d) (13e, 13f), respectively. The first and the second pressing surfaces (13a, 13b) (13c, 13d) (13e, 13f) are divided into the respective two regions on each of the plate-pressing surfaces (12a to 12c) separated by the virtual surfaces (S1 to S3) perpendicular to the respective plate-pressing surfaces (12a to 12c) at the intersection lines (C1 to C3).

[0098] As shown in Figs. 16(a) and (b), first and second acting sections (82a, 82b) in contact with the first and the second pressing surfaces (13a, 13b) are arranged at the ends processed to minute arc shapes of the pressure-receiving plate 81a, first and second acting sections (82c, 82d) in contact with the first and the second pressing

surfaces (13c, 13d) are arranged at the ends processed to minute arc shapes of the pressure-receiving plate 81b, and first and second acting sections (82e, 82f) in contact with the first and the second pressing surfaces (13e, 13f) are arranged at the ends processed to minute arc shapes of the pressure-receiving plate 81c.

[0099] The first and the second acting sections (82a, 82b) (82c, 82d) (82e, 82f) are formed on the pressure-receiving sections (81a to 81c) such that the respective second distances d2 from the virtual surfaces (S1 to S3) to the second acting sections (82b, 82d, 82f) are shorter than the respective first distances d1 from the virtual surfaces (S1 to S3) to the first acting sections (82a, 82c, 82e).

[0100] As shown in Fig.15, the thick rounded shafts (74 a to 76a) of the connecting pins (74 to 76) are positioned in adjacent gaps (73j to 73k) of the first to the third lock plates (73a to 73c). A compression coil spring 83 is positioned in the gap 73j between the second lock plate 73b and the third lock plate 73c. The second lock plate 73b receives, by the compression coil spring 83, a biasing force along a direction separated from the third lock plate 73c, and the thick rounded shafts (74 a to 76a) of the connecting pins (74 to 76), upon receipt of the biasing force of the compression coil spring 83, are sandwiched by the first to the third lock plates (73a to 73c).

[0101] As shown in Fig.15, the lock plates (73a to 73c) are held at the holding section 12 by contacting the pressure-receiving plates (81a to 81c) to the plate-pressing surfaces (12a to 12c), and the outer circumferential surfaces (14i to 14k) of the lock plates (73a to 73c) are internally contacted to the inner circumferential surface 80a of the cylindrical section 80 of the drive cylinder 72. The lock plates (73a to 73c) are connected with the first control rotating member 71 and rotate integrally with the first control rotating member 71.

[0102] The first acting members (82a, 82c, 82e) shown in Figs.16(a) to (c) receive a force F perpendicular to a direction extending the central shaft line L from the first pressing surfaces (13a, 13c, 13 e) because of the generation of the cam torque of the advance direction (D1 direction) in the center shaft 7 from the first pressing surfaces (13a, 13c, 13e), and the second acting members (82b, 82d, 82f) receive a force F perpendicular to a direction extending the central shaft line L0 from the second pressing surfaces (13b, 13d, 13f) because of the generation of the cam torque of the lag direction (D2 direction) in the center shaft 7 from the second pressing surfaces (13b, 13d, 13f).

[0103] In the variable phaser 70 for the vehicle engine of the third example, the self-blocking effects based on the force F is generated similarly to the self-locking mechanism 11 of the first Example by making the friction angles (θ_1 , θ_2) to $\theta_1 < \tan^{-1}\mu$ and $\theta_2 < \tan^{-1}\mu$. Since, as shown in Figs 16 (a) to (c), the second distance d2 of the pressure-receiving plates (81a to 81c) of the third Example is shorter than the first distance d1 similar to the first Example, the self-locking effects by the cam torque along

the advance direction (D1 direction) is larger than the self-locking force by the cam torque along the lag direction (D2 direction).

[0104] The shape of the holding section integrally formed with the center shaft is not restricted to the holding section 12 of the first Example and the third Example having the regular hexagonal section, and it may be shaped as a flange having a regular polygonal section

10 Description of Symbols

[0105]

- 1 variable phaser for automobile engine
- 2, 2' drive rotating member
- 3 control rotating member
- 5 drive cylinder
- 6 cam shaft
- 10 relative phase angle changing mechanism
- 11 self-locking mechanism
- 12 holding section
- 13a, 13c, 13e first pressing surface
- 13b, 13d, 13f second pressing surface
- 14 lock plate
- 14a to 14c first to third lock plates
- 15a to 15c pressure receiving section
- 17a, 17c, 17e first acting sections
- 17b, 17d, 17f second acting sections
- 20 cylindrical section
- 20a inner circumferential surface of cylindrical section
- 22 reverse rotating mechanism
- 55 variable phaser for automobile engine
- 57 holding section
- 58 lock plate
- 58a, 58b first and second lock plates
- 59a, 59b pressure receiving section
- 60a, 60c first pressing surface
- 60b, 60d second pressing surface
- 14 lock plate
- 61a, 61c first acting section
- 61b, 61d second acting section
- 65 self-locking mechanism
- 70 variable phaser for automobile engine
- 73 lock plate
- 73a to 73c first to third lock plates
- 80 cylindrical section
- 80a inner circumferential surface of cylindrical section
- 81a to 81c pressure-receiving plate (freely attaching and detaching-pressure receiving section of claim 5)
- 82a, 82c, 81e first acting section
- 82b, 82d, 81f second acting section
- d1 first distance
- d2 second distance
- L0 central shaft line of cam shaft
- D1 advance direction
- D2 lag direction

S1 to S3 virtual surfaces

Claims

1. A variable phaser for an automobile engine comprising:

a drive rotating member having a cylindrical section and driven by a crank shaft;
a cam shaft supporting the drive rotating member in a coaxial and relatively rotating fashion;
a relative phase angle changing mechanism for changing an opening-closing timing of a valve by means of changing a relative phase angle of the cam shaft with respect to the drive rotating member; and

a self-locking mechanism including a holding section integrally formed in a shape of a flange on an outer periphery of the cam shaft, and a lock plate held to the cam shaft in a relative rotation disabling fashion by the holding section and contacted internally to an inner circumference surface of the cylindrical section, in which the holding section prevents misalignment of the relative phase angle by means of pressing the lock plate onto the inner circumference surface of the cylindrical section upon receipt of a cam torque generating along an advance direction or a lag direction, **characterized in that:**

plate-pressing surfaces pressing the lock plates are disposed at a plurality of positions almost equally separated along an outer circumferential direction of the holding section;

the lock plates are mounted the same number as the plate-pressing surfaces at a plurality of positions almost equally separated along an outer circumferential direction, and include pressure receiving sections at positions opposing to the plate-pressing surfaces; and

the plurality of the plate-pressing surfaces are configured by a first pressing surface pressing the lock plate upon receipt of the cam torque generating along the advance direction and a second pressing surface pressing the lock plate upon receipt of the cam torque generating along the lag direction.

2. The variable phaser for the automobile engine as claimed in Claim 1,
wherein each of the plate-pressing surfaces and the lock plates are disposed at three or more positions almost equally separated along the outer circumferential direction.

3. The variable phaser for the automobile engine as claimed in Claim 1 or 2,

wherein each of the first pressing surface and the second pressing surface are formed on the plate-pressing surface as two surfaces separated by a virtual surface passing a central shaft line of the cam shaft and perpendicular to the plate-pressing surface;

the pressure receiving sections include a first acting section to which a pressing force by the first pressing surface is exerted and a second acting section to which a pressing force by the second pressing surface is exerted; and

the first acting section and the second acting section are formed on the pressure receiving section such that a first distance from the virtual surface to the first acting section is different from a second distance from the virtual surface to the second acting section.

4. The variable phaser for the automobile engine as claimed in Claim 3,

wherein the first acting section and the second acting section are formed on the pressure receiving section such that the second distance is shorter than the first distance.

5. The variable phaser for the automobile engine as claimed in Claim 3 or 4

wherein the pressure receiving section is mounted on the lock plate in a freely attaching and detaching fashion.

Fig. 1

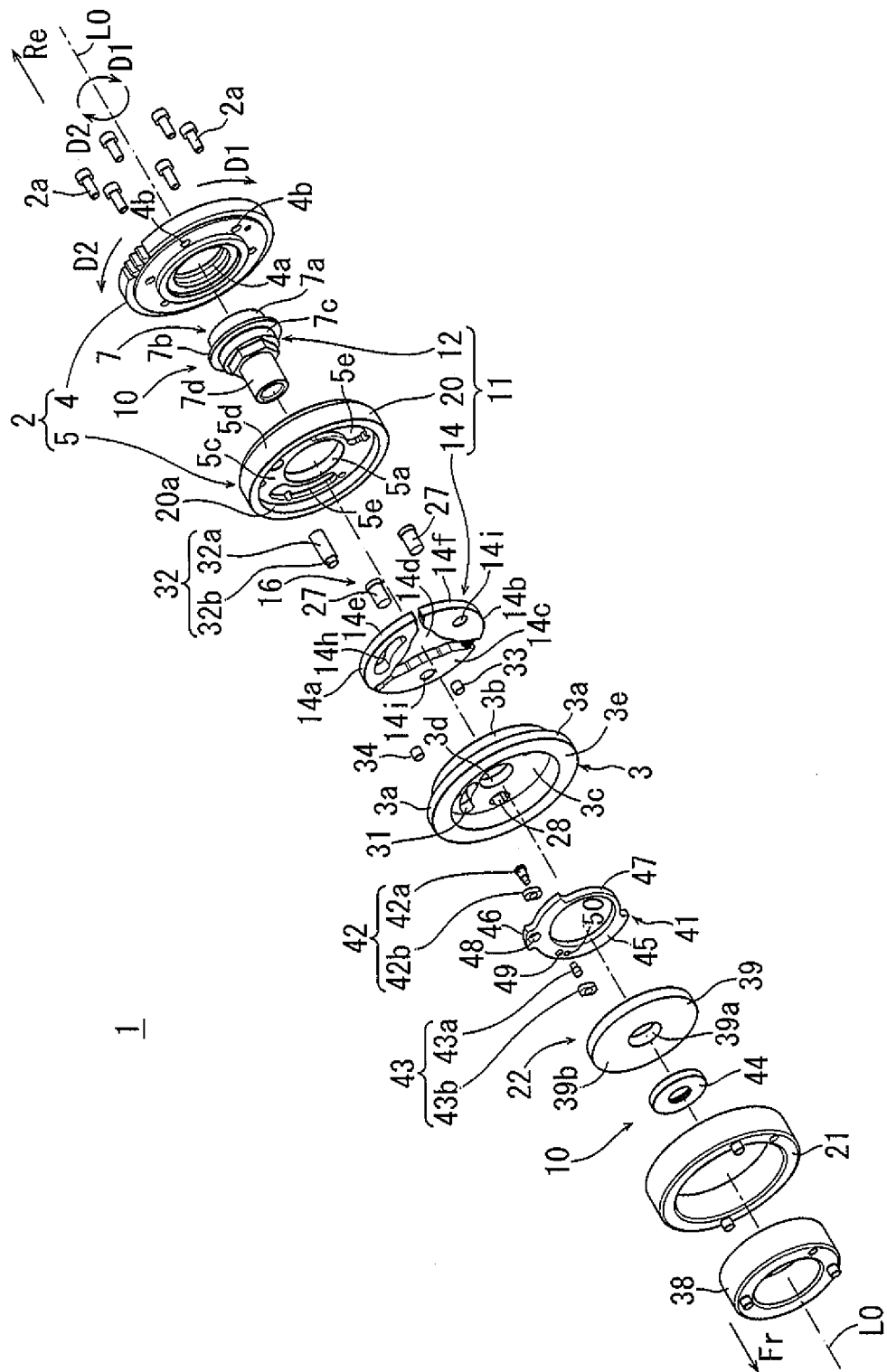


Fig. 2

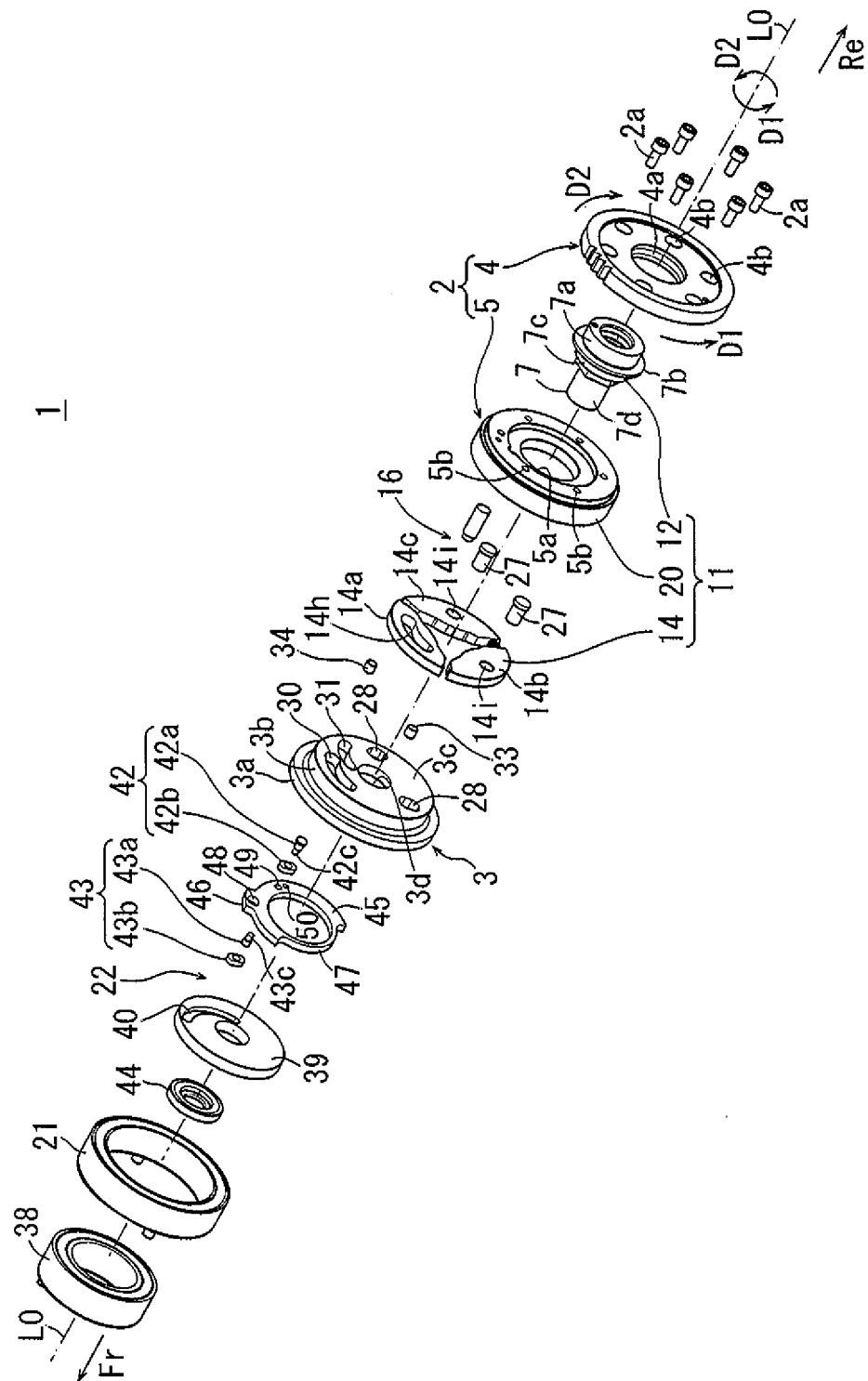


Fig. 3

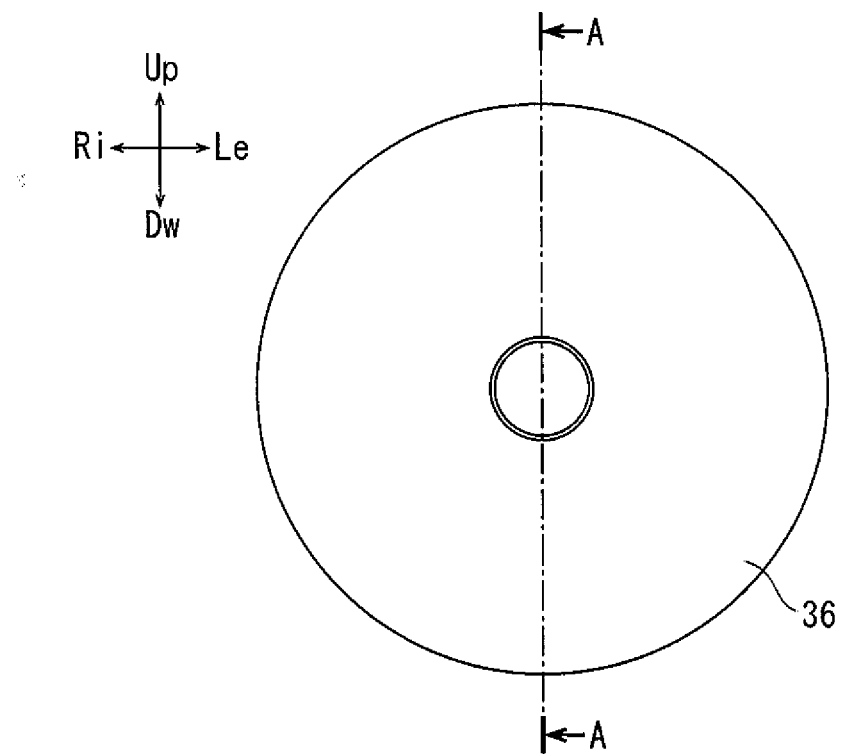


Fig. 4

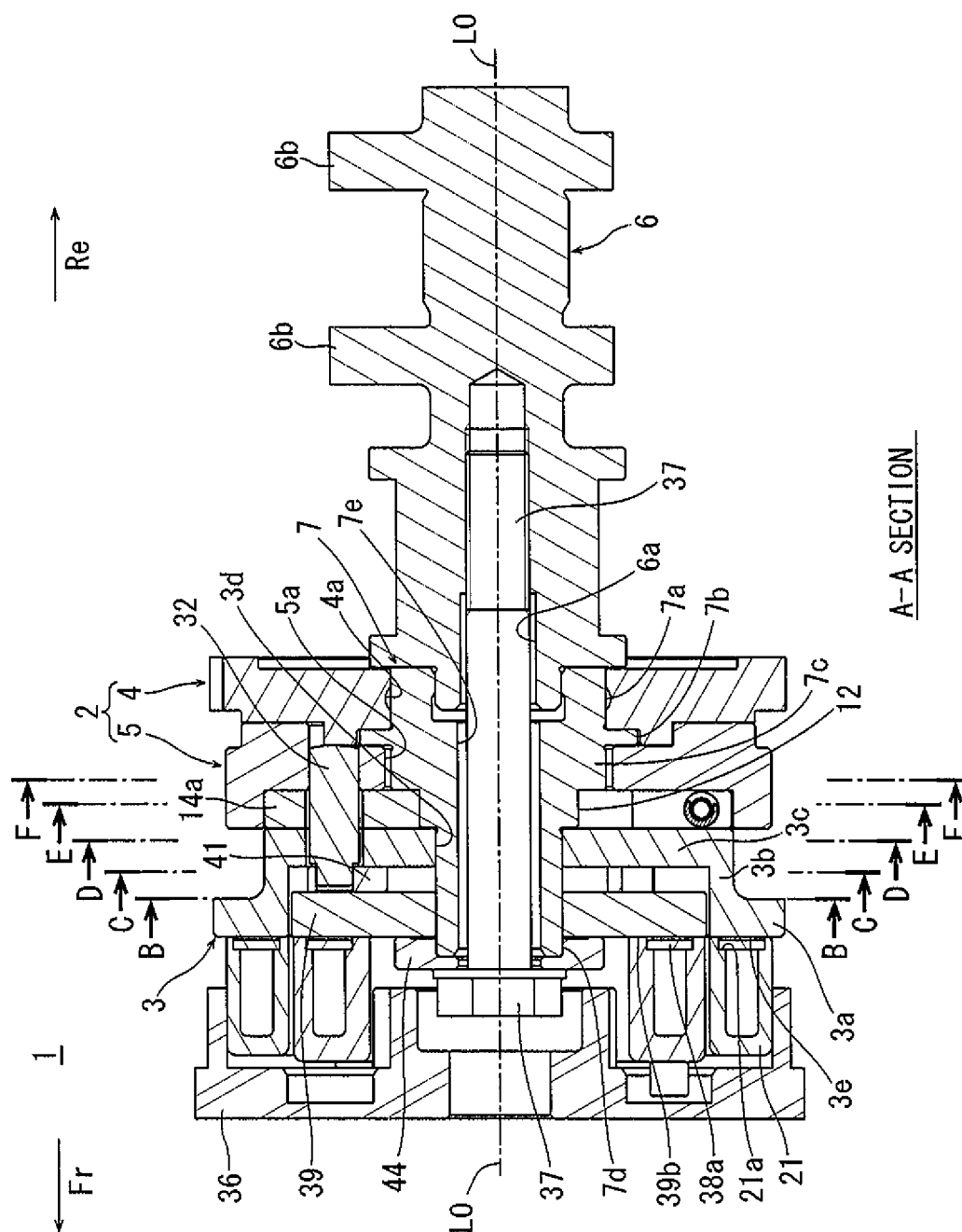


Fig. 5

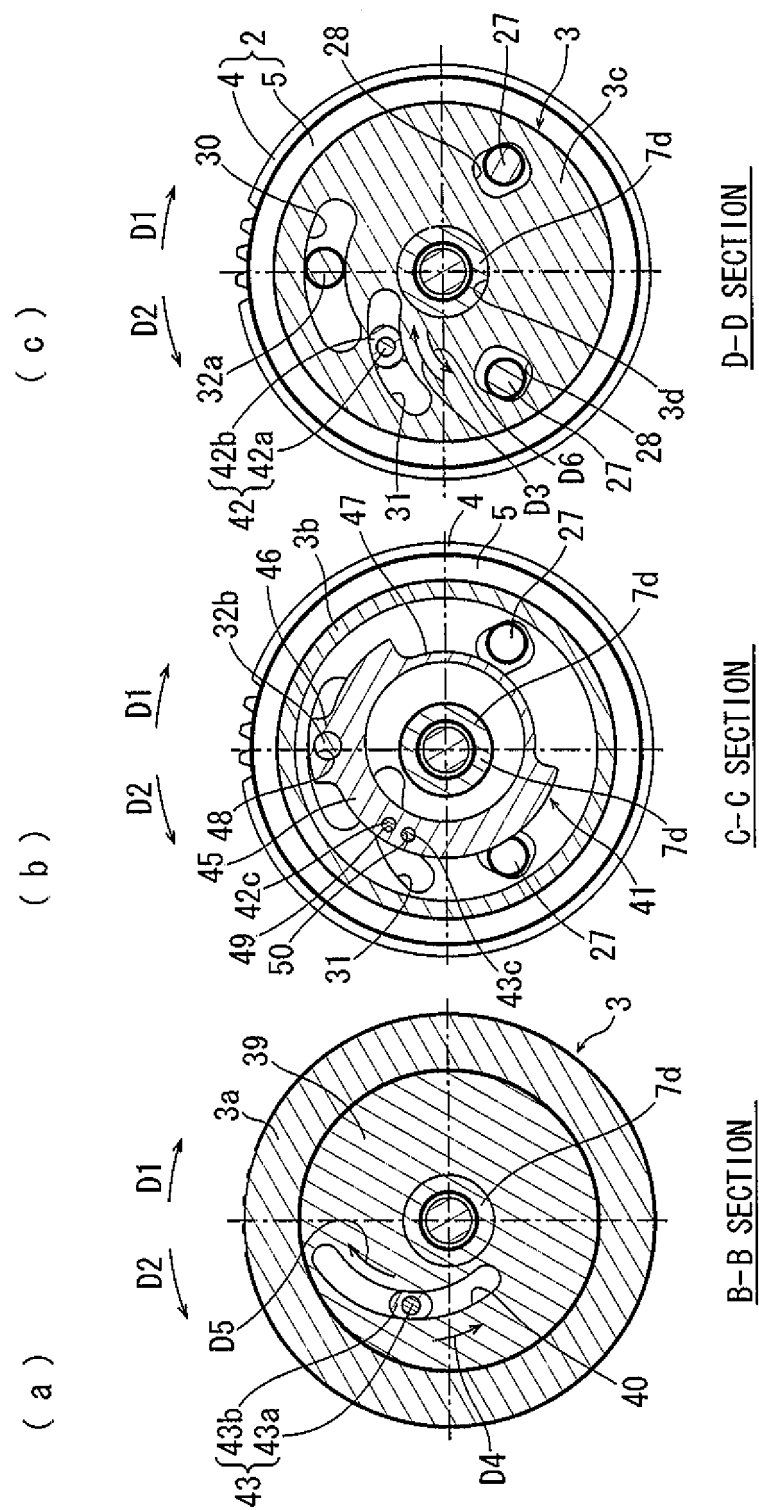


Fig. 6

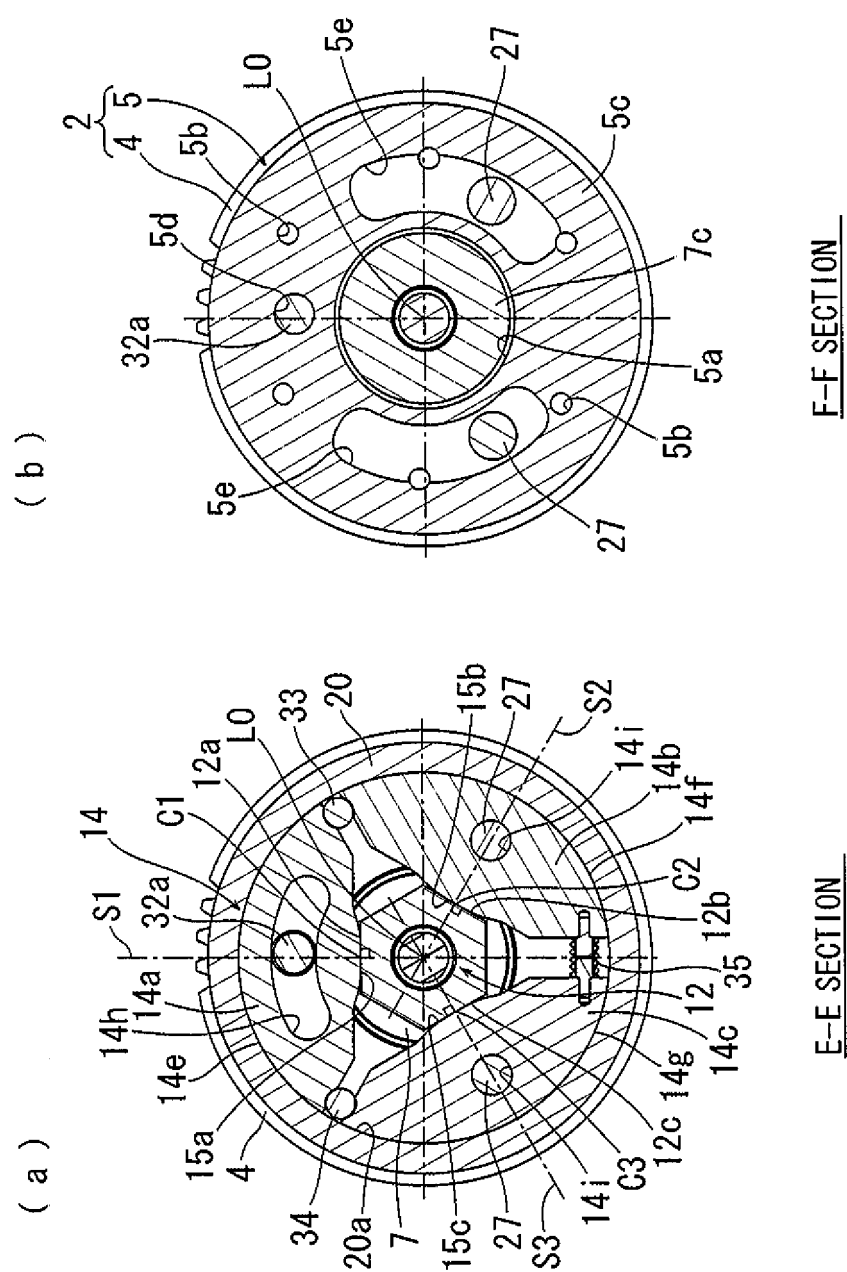


Fig. 7

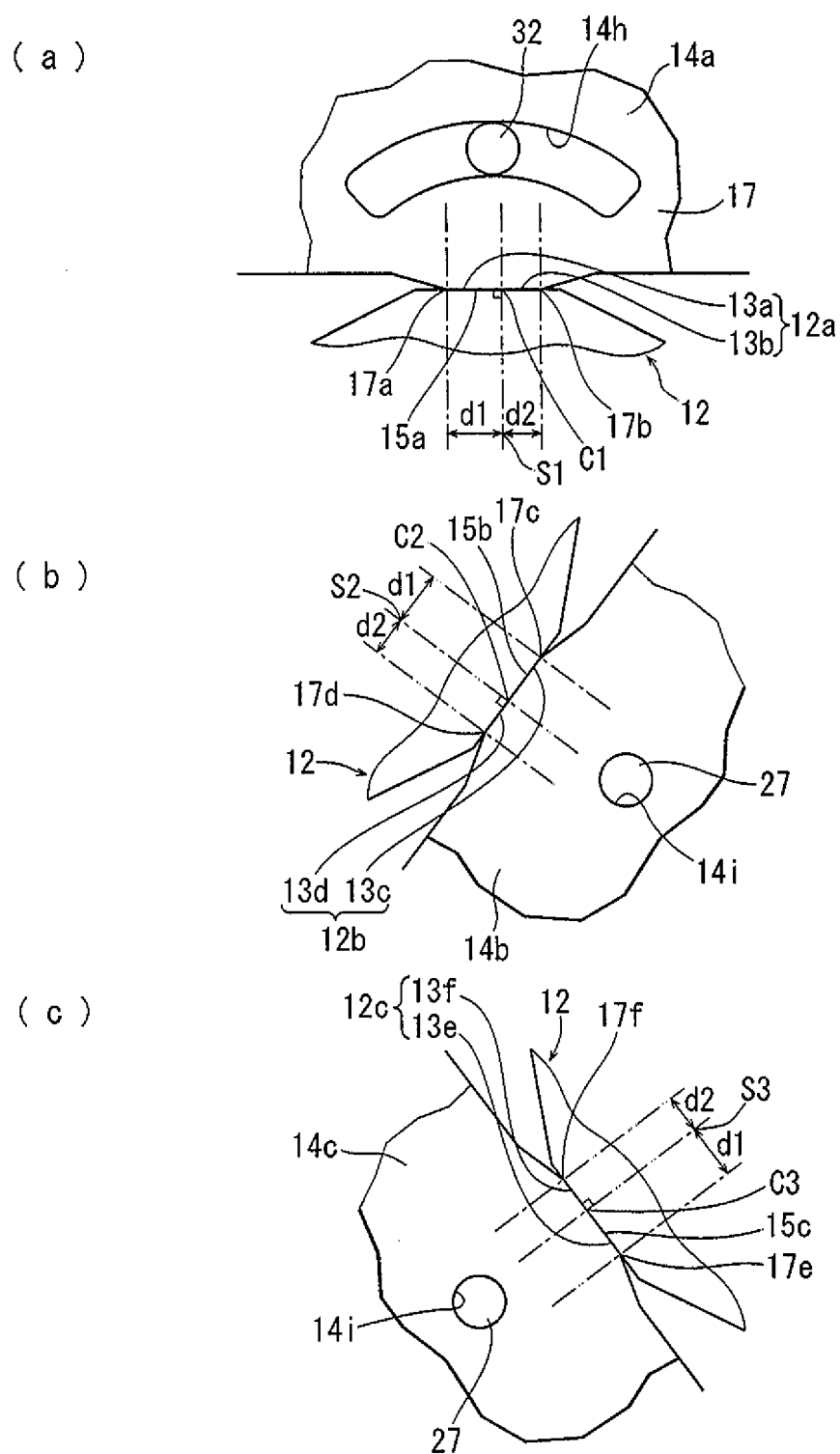


Fig. 8

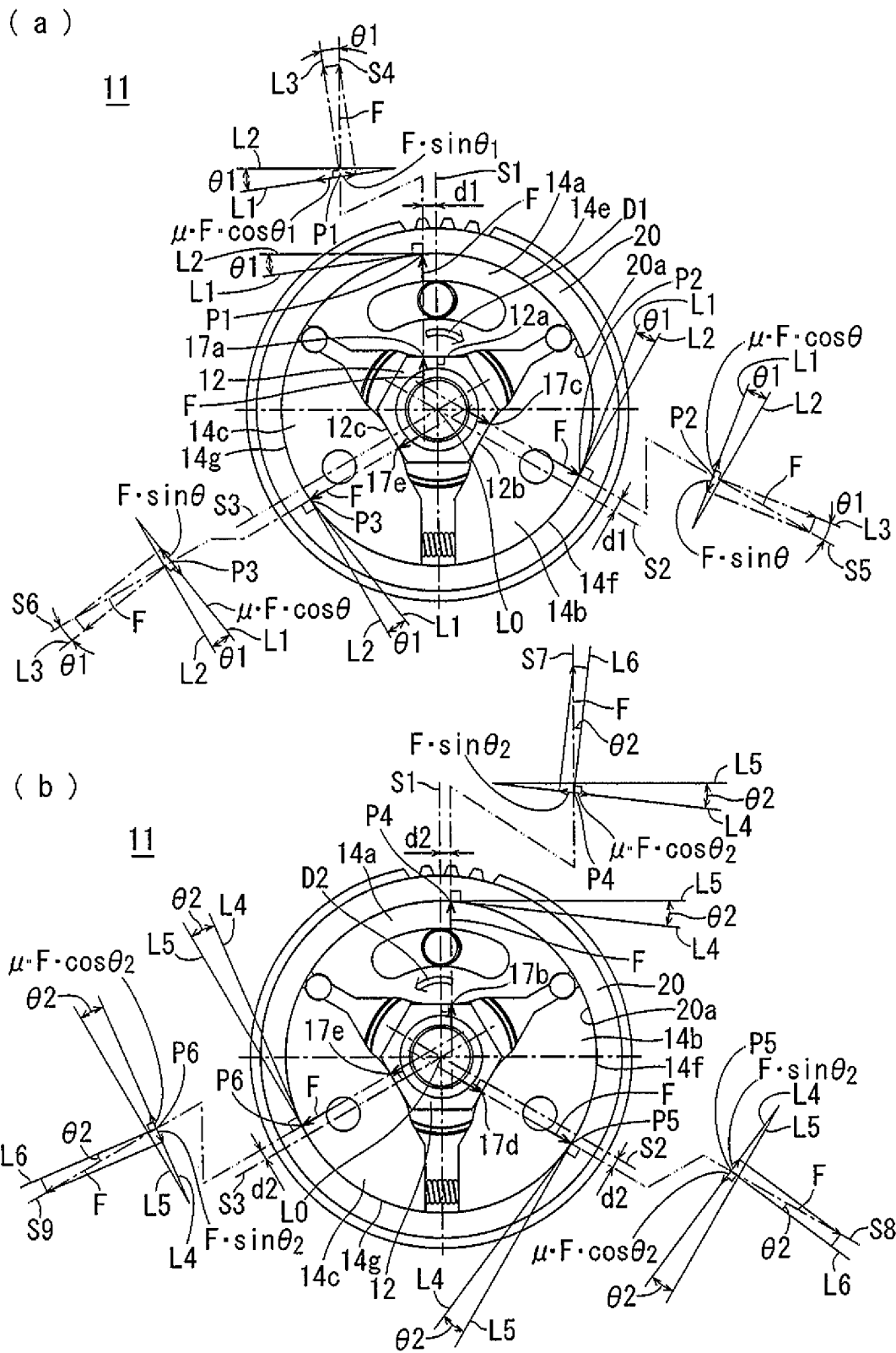


Fig. 9

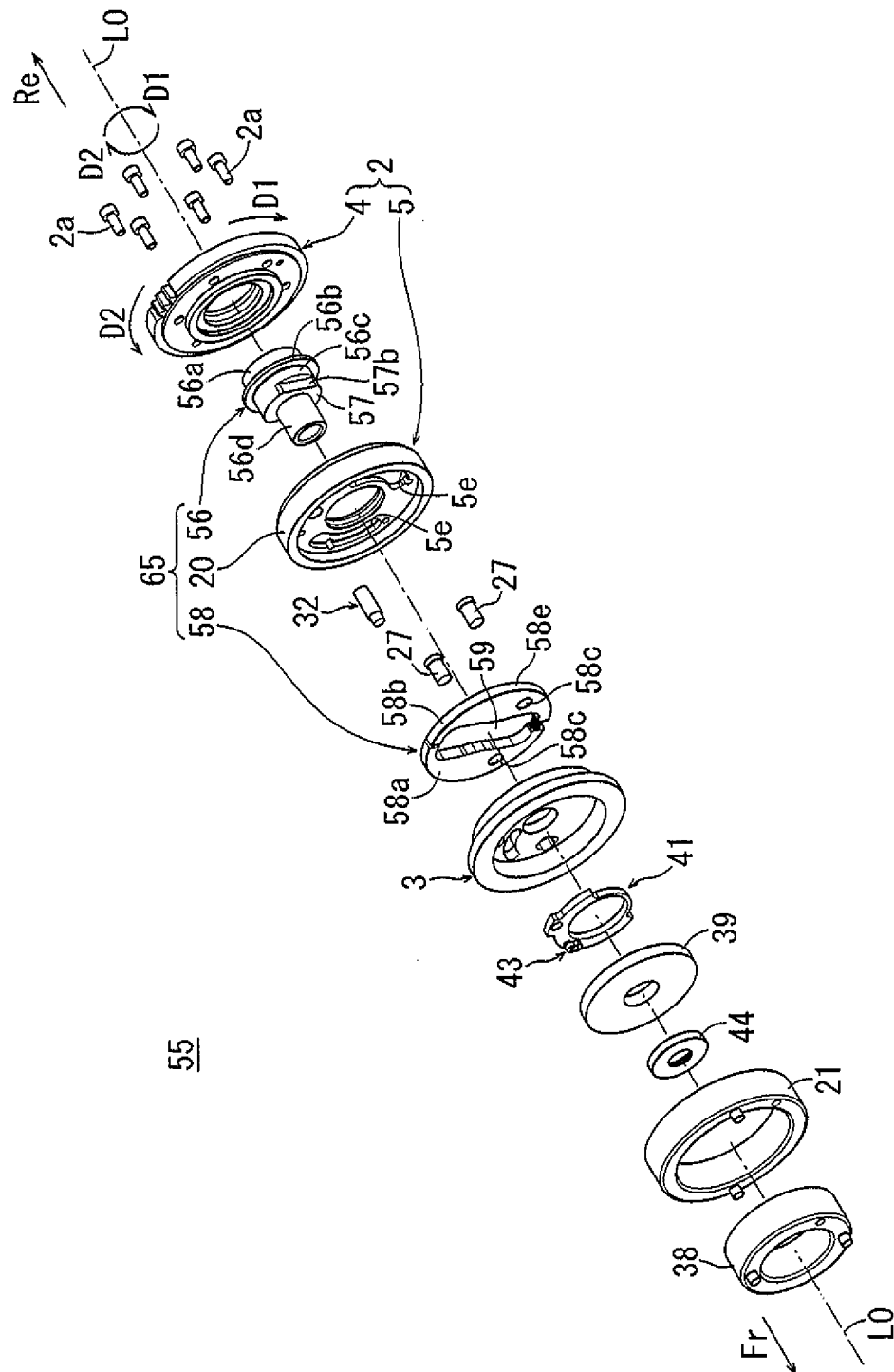


Fig. 10

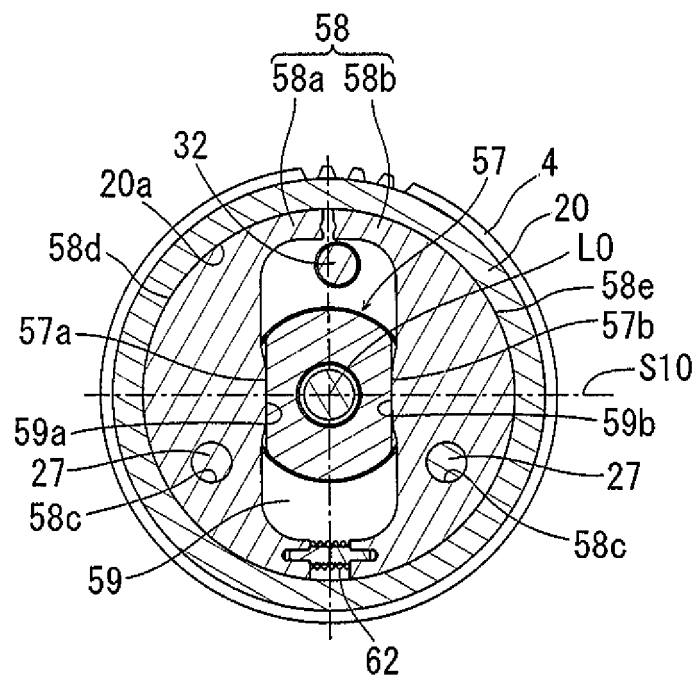
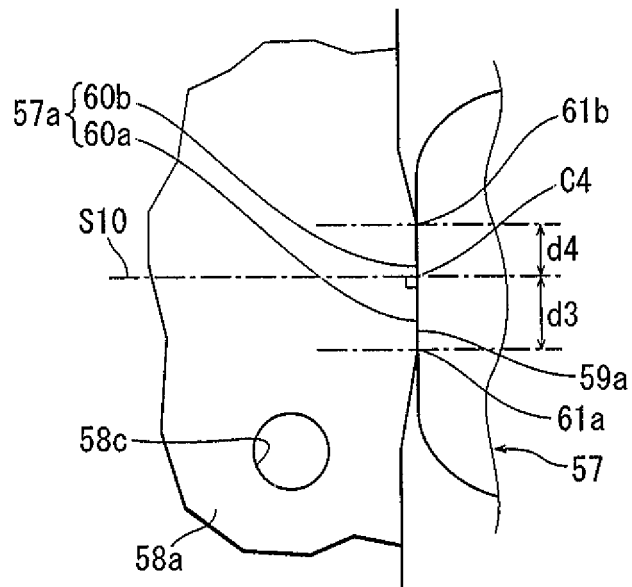


Fig. 11

(a)



(b)

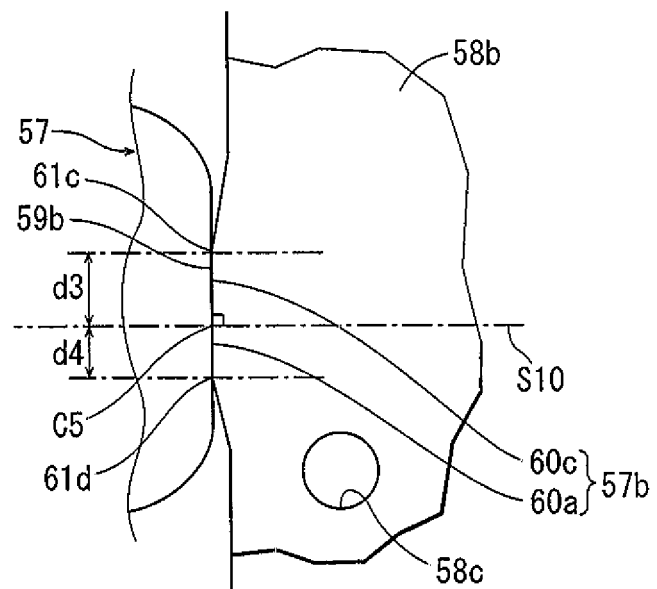
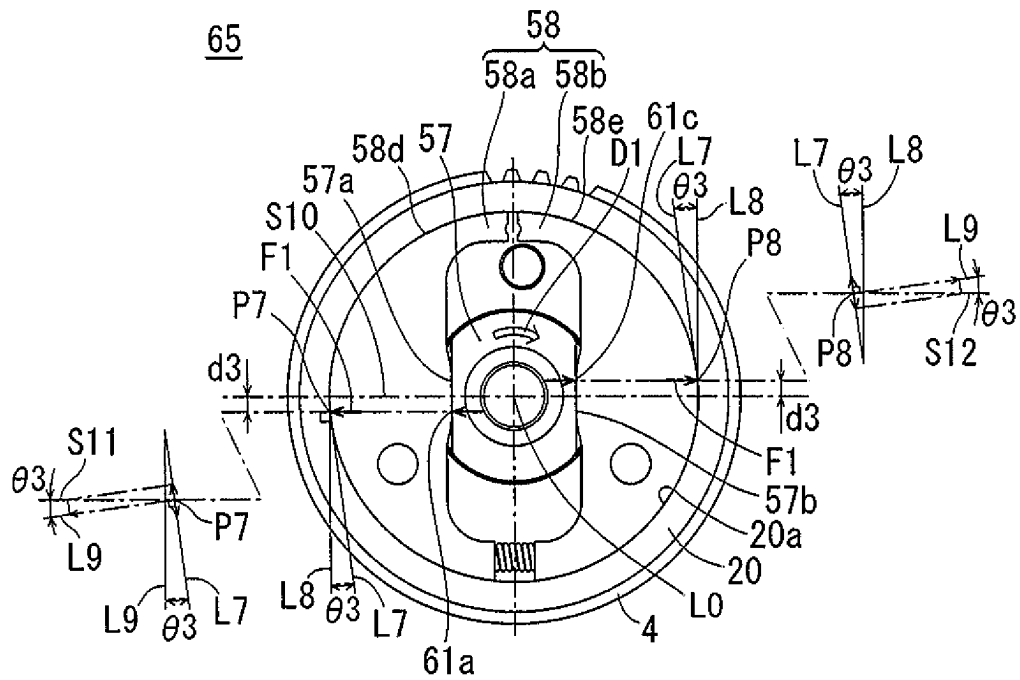


Fig. 12

(a)



(b)

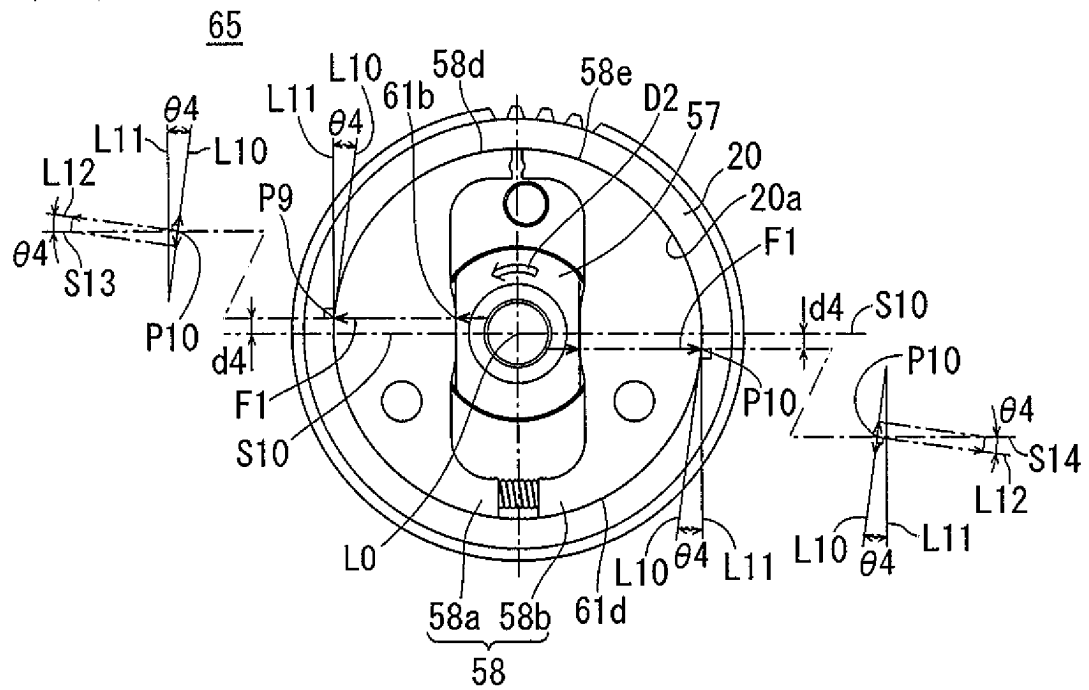


Fig. 13

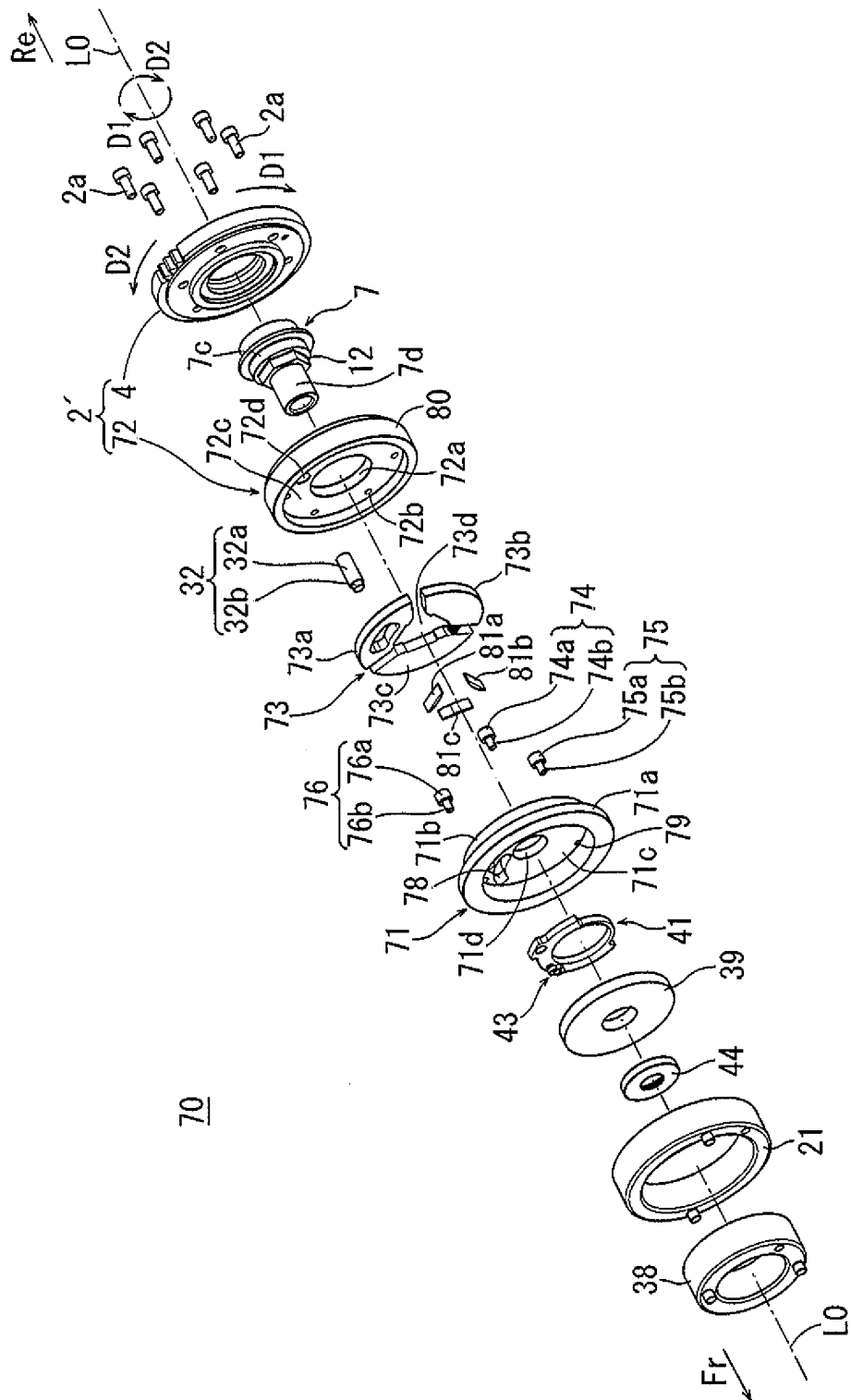


Fig. 14

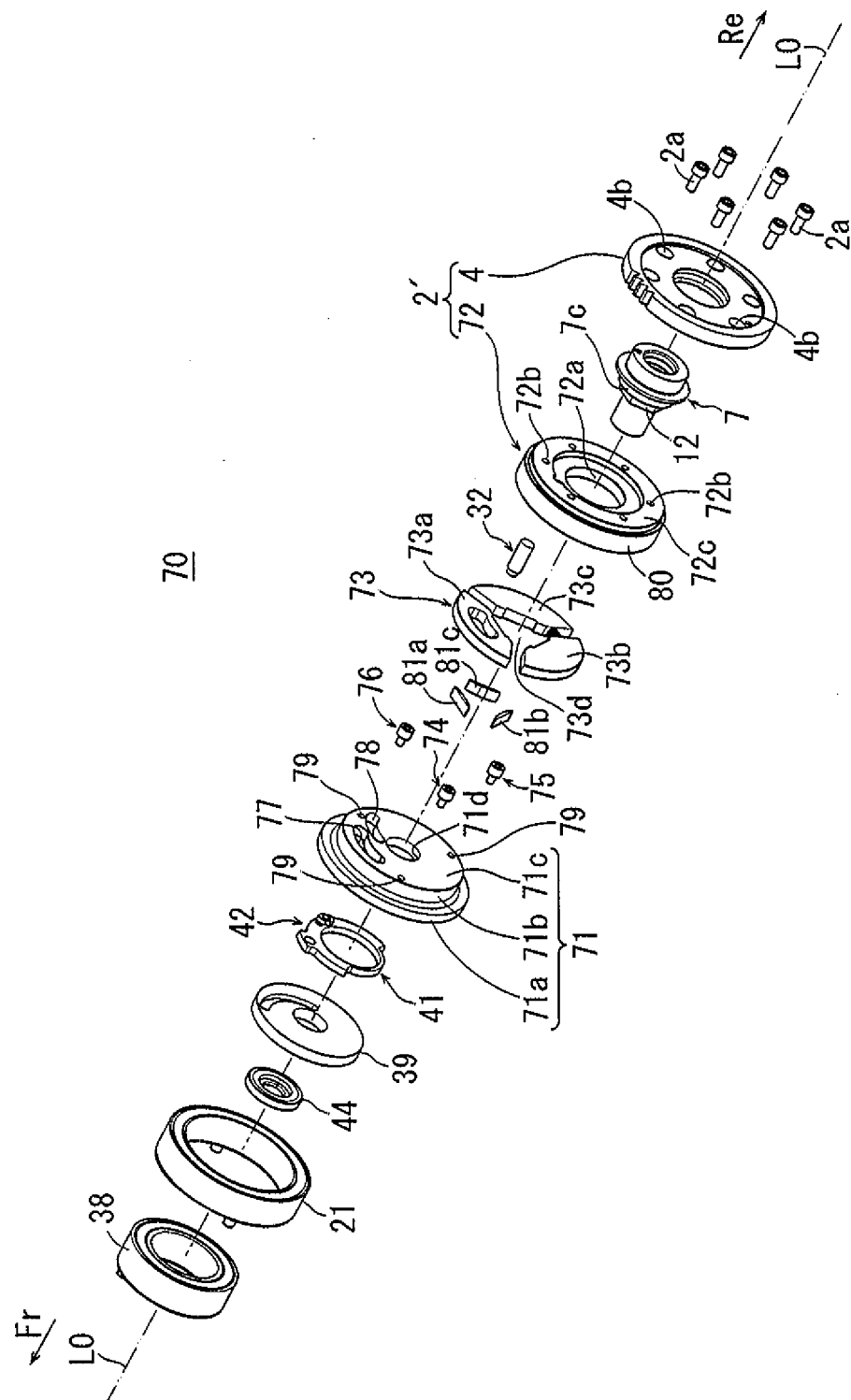


Fig. 15

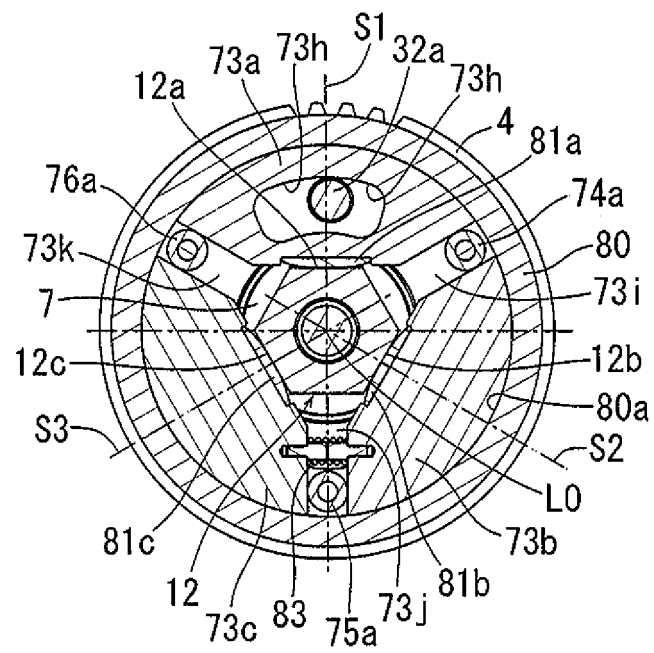
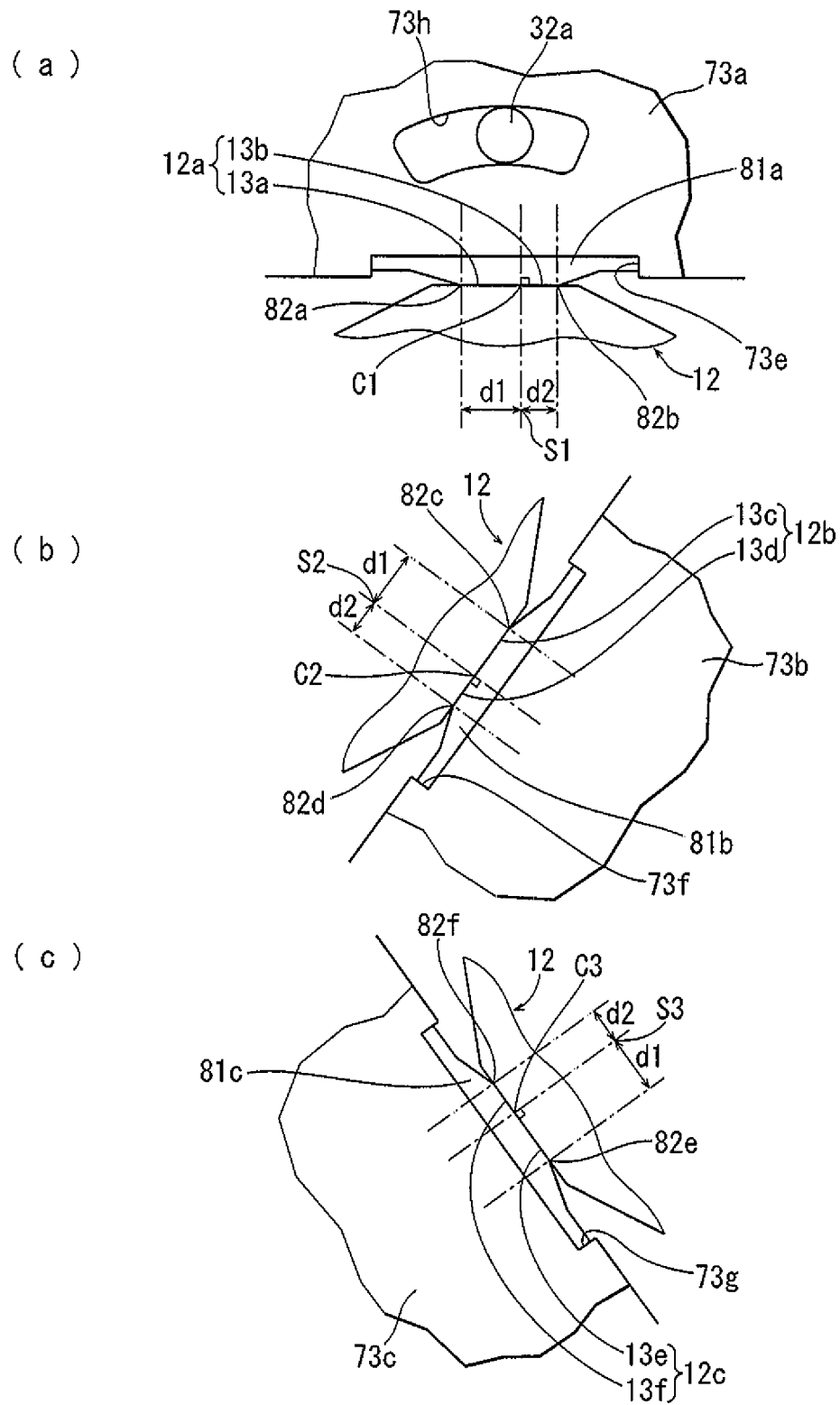


Fig. 16



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/076099

A. CLASSIFICATION OF SUBJECT MATTER

F01L1/34(2006.01) i, F01L1/356(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, F01L1/356

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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	WO 2012/049727 A1 (Nittan Valve Co., Ltd.), 19 April 2012 (19.04.2012), paragraphs [0004] to [0025], [0037] to [0076]; fig. 9 (Family: none)	1-5
A	WO 2011/145175 A1 (Nittan Valve Co., Ltd.), 24 November 2011 (24.11.2011), paragraphs [0006] to [0026], [0052] to [0073]; fig. 5, 7 (Family: none)	1-5
A	WO 2012/001812 A1 (Nittan Valve Co., Ltd.), 05 January 2012 (05.01.2012), fig. 5 (Family: none)	1-5

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

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Date of the actual completion of the international search
04 December, 2012 (04.12.12)Date of mailing of the international search report
11 December, 2012 (11.12.12)Name and mailing address of the ISA/
Japanese Patent Office

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/076099

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/113279 A1 (Nittan Valve Co., Ltd.), 07 October 2010 (07.10.2010), paragraphs [0063] to [0072] & EP 2415977 A1 & CN 102365429 A	1-5
A	WO 2010/046974 A1 (Nittan Valve Co., Ltd.), 29 April 2010 (29.04.2010), paragraphs [0037] to [0040]; fig. 6 & EP 2341222 A1 & CN 102197197 A	1-5

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