



(11)

EP 2 354 478 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.08.2011 Bulletin 2011/32

(51) Int Cl.:
F01L 1/053 (2006.01)
F01L 1/344 (2006.01)
F01L 1/34 (2006.01)

(21) Application number: 10014303.1

(22) Date of filing: 04.11.2010

(84) Designated Contracting States:
AL 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 RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: 10.02.2010 JP 2010028271

(71) Applicant: Aichi Machine Industry Co. Ltd.
Nagoya-shi,
Aichi 456-8601 (JP)

(72) Inventors:
• Ota, Takahira
Nagoya-shi
Aichi 456-8601 (JP)
• Horibe, Takehiro
Nagoya-shi
Aichi 456-8601 (JP)

(74) Representative: Schmitz, Hans-Werner
Hoefer & Partner
Patentanwälte
Pilgersheimer Strasse 20
81543 München (DE)

(54) Valve timing control apparatus and internal combustion engine equipped with the same

(57) A valve timing control apparatus for changing a relative rotational phase of a camshaft (8 or 10) with respect to a crankshaft (2) using a hydraulic pressure of a hydraulic oil supplied from an oil pump (16) includes a chain cover (4, 204, 304), a phase changing mechanism (30), a selector valve (18), and an intermediate oil passage. The chain cover (4, 204, 304) defines a valve chamber (12, 212, 312) having an inlet port (15b, 215b, 315b) for the hydraulic oil, an advancement port (15a, 215a, 315a), and a retardation port (15c, 215c, 315c). The phase changing mechanism (30) is coupled to an end portion of the camshaft (8 or 10) with the phase changing mechanism (30) being at least partially covered by the chain cover (4, 204, 304). The phase changing mechanism (30) has a plurality of hydraulic pressure chambers including an advancement chamber (38A) and a retardation chamber (38B). The selector valve (18) is housed in the valve chamber (12, 212, 312) of the chain cover (4, 204, 304), and configured and arranged to selectively open the advancement port (15a, 215a, 315a) or the retardation port (15c, 215c, 315c). The intermediate oil passage forming member (50, 150, 250, 350) is for conveying the hydraulic oil in the valve chamber (12, 212, 312) of the chain cover (4, 204, 304) from the advancement port (15a, 215a, 315a) of the valve chamber (12, 212, 312) to the advancement chamber (38A) of the phase changing mechanism (30), and from the retardation port (15c, 215c, 315c) of the valve chamber (12, 212, 312) to the retardation chamber (38B) of the phase changing mechanism (30).

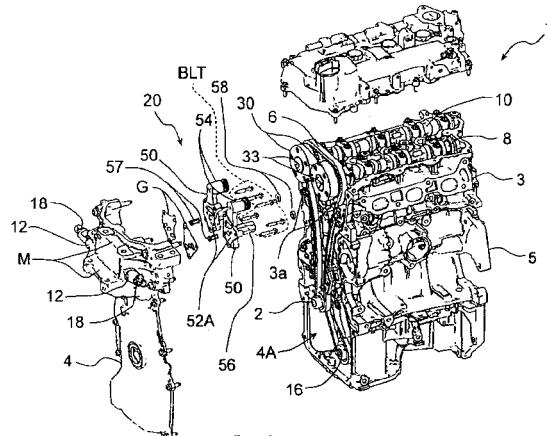


FIG. 1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Japanese Patent Application No. 2010-028271, filed on February 10, 2010. The entire disclosure of Japanese Patent Application No. 2010-028271 is hereby incorporated herein by reference.

BACKGROUND

Field of the Invention

[0002] The present invention relates to a valve timing control apparatus and an internal combustion engine equipped with the same.

Background Information

[0003] A conventional valve timing control apparatus of this type has been proposed (e.g., in Japanese Laid-Open Patent Publication No. 2001-82115) which comprises a variable valve timing control mechanism provided on an end portion of a camshaft so as to be coaxial with respect to the camshaft; a selector valve that serves to supply and discharge an hydraulic oil to and from the variable valve timing control mechanism; and a cover member that covers the variable valve timing control mechanism. The apparatus changes the open and close timings of an intake valve and an exhaust valve by supplying the hydraulic oil from an oil pump to the variable valve timing control mechanism through the cover member and changing a rotational phase of the camshaft with respect to a crankshaft.

[0004] In order to reduce the size of the valve timing control apparatus, a valve chamber for arranging the selector valve, a shaft section having an oil passage for directing hydraulic oil from the selector valve to an inside of an hydraulic oil chamber inside the variable valve timing control mechanism, and a connecting section for connecting and communicating between the inside of the selector valve chamber and the oil passage of the shaft section are formed as integral parts of the cover member and the cover member is attached to a cylinder head with the shaft section inserted into the variable valve timing control mechanism such that the shaft section is coaxial with respect to the camshaft.

SUMMARY

[0005] In an internal combustion engine, a chain cover for covering a timing chain serving to drive a valve device is typically attached to the cylinder head. Consequently, with the valve timing control apparatus described above, it is necessary to attach the cover member to the cylinder head with the chain cover disposed in-between and a large opening must be formed in the chain cover in order

to attach the cover member. As a result, it is difficult to ensure that the chain cover is sufficiently strong. In particular, it is imperative to ensure that the chain cover is strong when an engine mount for attaching the internal combustion engine to the vehicle body is provided on the chain cover. Although it is acceptable to form the cover member and the chain cover as a one-piece integral unit, in some cases doing so makes it difficult to machine the oil passages.

[0006] The object of the present invention is to provide a valve timing control apparatus with which the oil passage structure can be easily established while ensuring that the chain cover has sufficient strength.

[0007] The means the present invention adopts in order to achieve at least a portion of the aforementioned object will now be explained.

[0008] According to one aspect of the present invention, a valve timing control apparatus for changing a relative rotational phase of a camshaft with respect to a crankshaft using a hydraulic pressure of a hydraulic oil supplied from an oil pump includes a chain cover, a phase changing mechanism, a selector valve, and an intermediate oil passage forming member. The chain cover defines a valve chamber having an inlet port for the hydraulic oil, an advancement port, and a retardation port. The phase changing mechanism is coupled to an end portion of the camshaft with the phase changing mechanism being at least partially covered by the chain cover. The phase changing mechanism has a plurality of hydraulic pressure chambers including an advancement chamber and a retardation chamber. The selector valve is housed in the valve chamber of the chain cover, and configured and arranged to selectively open the advancement port or the retardation port. The intermediate oil passage forming member is for conveying the hydraulic oil in the valve chamber of the chain cover from the advancement port of the valve chamber to the advancement chamber of the phase changing mechanism, and from the retardation port of the valve chamber to the retardation chamber of the phase changing mechanism.

[0009] In the valve timing control apparatus according to the present invention, a valve chamber for attaching the selector valve is formed as an integral part of the chain cover and an oil passage for supplying the hydraulic oil from the selector valve to the inside of the hydraulic oil chamber is provided in a separate intermediate oil passage forming member. As a result, machining of the oil passage can be accomplished more easily. Also, since it does not have the valve chamber, the intermediate oil passage forming member can be made more compact than a conventional cover member in which the valve chamber and the oil passages are formed integrally. Consequently, even if it becomes necessary to form an opening in the chain cover in order to attach the intermediate oil passage forming member to the chain cover, the opening can be made smaller than in a conventional apparatus. Furthermore, a valve timing control apparatus according to the present invention is contrived such that

the intermediate oil passage forming member can be attached to the chain cover without forming an opening in the chain cover. As a result, the oil passage structure can be easily established while ensuring that the chain cover has sufficient strength.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Referring now to the attached drawings which form a part of this original disclosure:

[0011] Figure 1 is a schematic view showing constituent features of an internal combustion engine 1 equipped with a valve timing control apparatus 20 according to an embodiment to the present invention.

[0012] Figure 2 is a cross sectional view showing an axial cross section of a phase changing mechanism 30.

[0013] Figure 3 is a cross sectional view of the phase changing mechanism 30 showing a cross section that is perpendicular to the axial direction.

[0014] Figure 4 is a side view of a chain cover 4.

[0015] Figure 5 is a rear view of the chain cover 4.

[0016] Figure 6 is an enlarged view showing a portion of the chain cover 4 where valve chambers 12 and 12 are formed.

[0017] Figure 7 is an external view showing an external appearance of an intermediate oil passage forming member 50.

[0018] Figure 8 is a side view of the intermediate oil passage forming member 50.

[0019] Figure 9 is a frontal view of the intermediate oil passage forming member 50.

[0020] Figure 10 is a cross sectional view showing an oil passage structure of the valve timing control apparatus 20.

[0021] Figure 11 is a frontal view of an intermediate oil passage forming member 150.

[0022] Figure 12 is a side view of the intermediate oil passage forming member 150.

[0023] Figure 13 cross sectional view showing an oil passage configuration.

[0024] Figure 14 is an enlarged view showing contact surface sections 214 and 214 of a chain cover 204.

[0025] Figure 15 is a perspective view showing the shape of a mounting surface 252A of an intermediate oil passage forming member 250.

[0026] Figure 16 cross sectional view showing an oil passage configuration.

[0027] Figure 17 is a schematic view showing constituent features of an internal combustion engine 301 equipped with a valve timing control apparatus 320 according to an embodiment to the present invention.

[0028] Figure 18 is an enlarged view showing forward contact surface sections 314 and 314 of the chain cover 304.

[0029] Figure 19 is an external perspective view showing an external appearance of the intermediate oil passage forming member 350.

[0030] Figure 20 is a side view of the intermediate oil

passage forming member 350.

[0031] Figure 21 is a frontal view of the intermediate oil passage forming member 350.

[0032] Figure 22 is a cross sectional view showing an oil passage structure of the valve timing control apparatus 320.

DETAILED DESCRIPTION OF EMBODIMENTS

10 [0033] Selected embodiments will now be explained with reference to the drawings. It will be apparent to those skilled in the art from this disclosure that the following descriptions of the embodiments are provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

FIRST EMBODIMENT

20 [0034] Figure 1 is a schematic view showing constituent features of an internal combustion engine 1 equipped with a valve timing control apparatus 20 according to an embodiment to the present invention. As shown in Figure 1, the valve timing control apparatus 20 of this embodiment is an apparatus contrived to change the open and close timings of the intake valves and exhaust valves (not shown) of an internal combustion engine 1 in which the intake valves and exhaust valves are opened and closed by rotating an intake camshaft 8 and an exhaust camshaft 10 using a timing chain 6. The timing chain 6 is arranged inside a chain chamber 4A covered by a chain cover 4 and serves to transmit rotation of a crankshaft 2 to the intake camshaft 8 and the exhaust camshaft 10. The valve timing control apparatus 20 comprises phase changing mechanisms 30 and 30 arranged on one end of each of the intake camshaft 8 and the exhaust camshaft 10, valve chambers 12 and 12 formed integrally on an engine mount section M of the chain cover 4, oil passage selecting control valves 18 and 18 that are inserted into the valve chambers 12 and 12, and intermediate oil passage forming members 50 and 50 that are arranged between the valve chambers 12 and 12 and the phase changing mechanisms 30 and 30 and form oil passages for an hydraulic oil.

25 [0035] Figure 2 is a cross sectional view showing an axial cross section of a phase changing mechanism 30, and Figure 3 is a cross sectional view of the phase changing mechanism 30 showing a cross section that is perpendicular to the axial direction. As shown in Figure 2, each of the phase changing mechanisms 30 has a vane rotor 32 and a housing 34. The vane rotor 32 is fixed coaxially to the intake camshaft 8 or the exhaust camshaft 10 with a cam bolt BLT, and the housing 34 houses the vane rotor 32 inside such the vane rotor 32 can rotate freely with respect to the housing 34. The vane rotor 32 has an open section 33 having an internal circumference that is open toward an opposite side of the vane rotor 32 as a side that abuts against the intake camshaft 8 or the

exhaust camshaft 10. The vane rotor 32 also has four vanes 36 that protrude in substantially radial directions from an external circumference, as shown in Figure 3.

[0036] As shown in Figure 2 and Figure 3, the housing 34 comprises a circular disk-shaped front plate 34a, a housing body 34b partitioned into four hydraulic pressure chambers by the four vanes 36, and a rear plate 34c having a sprocket S formed on an external circumference thereof. Each of the four hydraulic pressure chambers comprises an advancement chamber 38A and a retardation chamber 38B, making a total of four advancement chambers 38A and four retardation chambers 38B. Through passages 33A communicate from the advancement chambers 38A to the open section 33 of the vane rotor 32, and through passages 33B communicate from the retardation chambers 38B to the open section 33. The timing chain 6 is arranged on the sprocket S such that rotation of the crankshaft 2 is transmitted to the housing 34 and then to the intake camshaft 8 or the exhaust camshaft 10 through the vane rotor 32.

[0037] Figure 4 is a side view of the chain cover 4, Figure 5 is a rear view of the chain cover 4, and Figure 6 is an enlarged view of a portion of the chain cover 4 where the valve chambers 12 and 12 are formed. As shown in Figures 4 to 6, the valve chambers 12 and 12 are formed on a portion of the chain cover 4 where the engine mount section M is formed and have the form of generally cylindrical bottomed holes that open to the left and right with respect to the engine mount section M (left and right from the perspective of Figure 5). Each of the valve chambers 12 and 12 has three through passages 15a, 15b, and 15c that communicate with a rear side of the chain cover 4. The through passages 15a, 15b, and 15c of each of the valve chambers 12 and 12 open at each of two contact surface sections 14 and 14 that are machined to planar surfaces having the same height position on a rear side of the chain cover 4. In addition to the through passages 15a, 15b, and 15c, two bolt holes 14a and 14a are formed in each of the contact surface sections 14 and 14. Bolt holes 14b and 14b are also formed in a rear side of the chain cover 4 and machined to have a planar contact surface arranged at the same height position as the contact surface sections 14 and 14.

[0038] Figure 7 is an external view showing an external appearance of an intermediate oil passage forming member 50, Figure 8 is a side view of the intermediate oil passage forming member 50, Figure 9 is a frontal view of the intermediate oil passage forming member 50. As shown in Figures 7, 8, and 9, the intermediate oil passage forming member 50 comprises a base section 52 (connecting section) having substantially the shape of an isosceles triangle in a frontal view, a protruding shaft section 54 that protrudes from a vertex portion of the base section 52 at a substantially right angle with respect to the base section 52, and a protruding shaft section 56 (supply section) that protrudes from a position near a bottom side of the base section 52 (corresponding to a base of the triangle) at a substantially right angle with

respect to the base section 52 in the same direction as the protruding shaft section 54.

[0039] Two oil passages 52a and 52b are provided in the base section 52 and run from the base side toward the vertex side substantially parallel to the legs of the triangle, which join the base to the vertex. In this embodiment, the oil passages 52a and 52b are formed within the base section 52. This eliminates the need to form an oil passage leading from the valve chamber to the phase changing mechanism in the chain cover. As a result, the oil passages can be formed more easily. Two communication passages 53a and 53b arranged to communicate with the two oil passages 52a and 52b are also provided such that they open through an mounting surface 52A formed on the opposite face of the base section 52 as the face from which the protruding shaft sections 54 and 56 protrude. The oil passages 52a and 52b are plugged with blind plugs (not shown) at portions of the base section corresponding to the base of the triangular shape, and the mounting surface 52A is machined to be a flat planar surface. Bosses B, B, and B each having a bolt hole formed therein are formed the three sides, respectively, of the base section 52, i.e., the sides corresponding to the two legs and the base of the triangular shape, and each of the bolt holes passes through to the mounting surface 52A.

[0040] Two intra-shaft oil passages 54a and 54b are formed in the protruding shaft section 54 such that they run from a tip end face of the protruding shaft section 54 to the two oil passages 52a and 52b formed inside the base section 52. As shown in Figure 7 and Figure 8, an annular oil passage 54A is formed in an external circumferential surface of the protruding shaft section 54 in a position closer to the tip end face. Two seal ring grooves SG1 and SG2 are formed in positions even closer to the tip end face than the annular groove 54A, and a seal ring groove SG3 is formed in a position closer to the base section 52 than the annular groove 54A. As shown in Figure 9, a notched section 54B is formed in the annular groove 54A by cutting away an external circumferential surface corresponding to approximately 1/3 of the circumferential length of the annular groove 54A such that the intra-shaft oil passage 54a and the annular groove 54A are in communication with each other.

[0041] As shown in Figures 7 to 9, an intra-shaft oil passage 56a is formed in the protruding shaft section 56 and runs from a tip end face to the mounting surface 52A. An internal diameter of the intra-shaft oil passage 56a changes in a step-like fashion at an intermediate position along its length such that an enlarged diameter section 56a' having a larger internal diameter exists closer to the mounting surface 52A and a smaller diameter section exists closer to the tip end of the protruding shaft section 56. The enlarged diameter section 56a' houses an oil filter 57 serving to filter impurities contained in the hydraulic oil.

[0042] The oil passage structure of the valve timing control apparatus 20 will now be explained in detail. Fig-

ure 10 is a cross sectional view showing an oil passage structure of the valve timing control apparatus 20. As shown in Figure 1, the intermediate oil passage forming members 50 and 50 are mounted to the chain cover 4 with the mounting surfaces 52A and 52A of the base sections 52 and 52 abutted against the contact surface sections 14 and 14 of the chain cover 4 through metal gaskets G and G and are fastened to the chain cover 4 with three bolts BLT each. Thus, the intermediate oil passage forming members 50 and 50 are attached to an inside of the chain cover 4. More specifically, the intermediate oil passage forming members 50 and 50 are attached to the chain cover 4 such that the communication passages 53a and 53a of the intermediate oil passage forming members 50 and 50 connect to the respective through passages 15a and 15a of the chain cover 4, the communication passages 53b and 53b of the intermediate oil passage forming members 50 and 50 connect to the respective through passage 15c and 15c of the chain cover 4, and the intra-shaft oil passages 56a and 56a (expanding diameter sections 56a' and 56a') of the intermediate oil passage forming members 50 and 50 connect to the respective through passages 15b and 15b of the chain cover 4. When the chain cover 4 is attached to a cylinder head 3 such that it covers the chain chamber 4, the intermediate oil passage forming members 50 and 50 are arranged between the chain cover 4 and the cylinder head 3 and the protruding shaft sections 54 and 54 of the intermediate oil passage forming members 50 and 50 are inserted together with seal rings (not shown) in a coaxial manner into the open sections 33 and 33 formed in the vane rotors 32 and 32 of the phase changing mechanisms 30 and 30. Also, the tip end faces of the protruding shaft sections 56 and 56 abut against the cylinder head 3 through seal members 58 and 58. Thus, the intra-shaft oil passages 54a of the intermediate oil passage forming members 50 and 50 are connected to and in communication with the advancement chambers 38A of the respective phase changing mechanisms 30 and 30 through the respective through passages 33A, and the intra-shaft oil passage 54b of the intermediate oil passage forming members 50 and 50 are connected to and in communication with the retardation chambers 38B of the respective phase changing mechanisms 30 and 30 through the respective through passages 33B. Meanwhile, the tip ends of the intra-shaft oil passages 56a of the intermediate oil passage forming members 50 and 50 are connected to oil passage openings 3a and 3a formed in the cylinder head 3. The oil passage openings 3a communicate with an internal block oil passage (not shown) formed inside a cylinder block 5 through which hydraulic oil pumped by the oil pump 16 flows.

[0043] When the intermediate oil passage forming members 50 and 50 are installed so as to be sandwiched between the chain cover 4 and the cylinder head 3, hydraulic oil pumped from the oil pump 16 flows through the internal block oil passage (not shown) formed in side the cylinder block and into the intra-shaft oil passages

56a and 56a inside the protruding shaft sections 56 and 56 of the intermediate oil passage forming members 50 and 50 from the oil passage openings 3a and 3a as shown in Figure 10. After flowing into the intra-shaft oil passages 56a and 56a, the hydraulic oil is conveyed to the valve chambers 12 and 12 by the through passages 15b and 15b. Depending on the positions of the oil passage selecting control valves 18 and 18 (i.e., depending on which of the through passages 15a and 15a, and 15c and 15c are opened by the oil passage selecting control valves 18 and 18), the hydraulic oil then flows either through the through passages 15a and 15a, the communication passages 53a and 53a, and the oil passages 52a and 52a or through the through passages 15c and 15c, the communication passages 53c and 53c, and the oil passages 52b and 52b. If the hydraulic oil flows through the oil passages 52a and 52a, then the hydraulic oil passes through the intra-shaft oil passages 54a and 54a, the annular grooves 54A and 54A, the through passages 33A and 33A, and into the advancement chambers 38A and 38A. Meanwhile, if the hydraulic oil flows through the oil passages 52b and 52b, then the hydraulic oil passes through the intra-shaft oil passages 54b and 54b, the through passages 33B and 33B, and into the retardation chambers 38B and 38B. When the hydraulic oil flows into the advancement chambers 38A and 38A or the retardation chambers 38B and 38B, the vane rotors 32 and 32 rotate relative to the housings 34 and 34 and change the open and close timings of the intake valves and the exhaust valves.

[0044] With the valve timing control apparatus 20 according to the embodiment described above, machining of the oil passages can be accomplished more easily because the valve chambers 12 and 12 to which the oil passage selecting valves 18 and 18 are attached are formed as integral portions of the chain cover 4 and the oil passages serving to convey hydraulic oil pumped by the oil pump 16 from the oil passage openings 3a and 3a of the cylinder head 3 to the valve chambers 12 and 12 and from the valve chambers 12 and 12 to the advancement chambers 38A and the retardation chambers 38B (i.e., the intra-shaft oil passages 56a, the communication oil passages 53a and 53b, the oil passages 52a and 52b, and the intra-shaft oil passages 54a and 54b) are provided in the intermediate oil passage forming members 50 and 50, which are separate entities from the chain cover 4. Moreover, since it is not necessary to form an opening in the chain cover 4 in order to attach the intermediate oil passage forming members 50 to the chain cover 4, the strength of the chain cover 4 is not degraded. As a result, the oil passage structure can be easily established while ensuring that the chain cover 4 has sufficient strength.

[0045] In the valve timing control apparatus 20 according to the first embodiment, the protruding shaft sections 56 and 56 having the intra-shaft oil passages 56a and 56a are provided on the intermediate oil passage forming members 50 and 50 and the protruding shaft sections 56

and 56 are abutted against the oil passage openings 3a and 3a of the cylinder head 3 through seal rings 58 and 58 such that hydraulic oil from the oil pump 16 can be supplied to the valve chambers 12 and 12. However, it is also acceptable not to provide the protruding shaft sections 56 and 56 on the intermediate oil passage forming members 50 and 50 and, instead, to form protruding sections 3A and 3A that protrude toward the chain cover 4 on the cylinder head 3, form oil passage openings 3a and 3a in the protruding sections 3A and 3A, and arrange and configure the protruding sections 3A and 3A such that they abut against the contact surface sections 14 and 14 of the chain cover 4 through seal rings, thereby enabling hydraulic oil pumped by the oil pump 16 to be supplied from the oil passage openings 3a and 3a to the valve chambers 12 and 12 through the through passages 15b and 15b of the contact surface sections 14 and 14.

[0046] Figure 11 is a frontal view of an intermediate oil passage forming member 150 according to a variation of the first embodiment, Figure 12 is a side view of the intermediate oil passage forming member 150, and Figure 13 is a cross sectional view of an oil passage configuration. As shown in Figure 11, the intermediate oil passage forming member 150 comprises a base section 152 shaped generally like a letter A in a frontal view and a protruding shaft section 154 provided at a vertex portion of the base section 152 and configured to protrude at a substantially right angle with respect to the base section 152. Two oil passages 152a and 152b are provided in the base section 152 and run from the tip ends of leg portions of the A-shape toward the vertex portion so as to be substantially parallel to diagonal sides that join the leg portions to the vertex portion of the A-shape. Two communication passages 153a and 153b arranged to communicate with the two oil passages 152a and 152b are also provided such that they open through an a mounting surface 152A formed on an opposite face of the base section 152 as a face from which the protruding shaft section 154 protrudes. The oil passages 152a and 152b are plugged with blind plugs (not shown) at the tip ends of the leg portions of the A-shape, and the mounting surface 152A is machined to be a flat planar surface. Bosses B, B, B, and B having a bolt hole formed therein are formed on the leg portions of the base section 152, and each of the bolt holes passes through to the mounting surface 152A. Two intra-shaft oil passages 154a and 154b are formed in the protruding shaft section 154 such that they run from a tip end face of the protruding shaft section 154 to the two oil passages 152a and 152b formed inside the base section 152.

[0047] As shown in Figure 12, an annular oil passage 154A is formed in an external circumferential surface of the protruding shaft section 154 in a position closer to the tip end face. Two seal ring grooves SG1 and SG2 are formed in positions even closer to the tip end face than the annular groove 154A, and a seal ring groove SG3 is formed in a position closer to the base section 152 than the annular groove 154A. As shown in Figure

11, a notched section 154B is formed in the annular groove 154A by cutting away an external circumferential surface corresponding to approximately 1/3 of the circumferential length of the annular groove 154A such that the intra-shaft oil passage 154a and the annular groove 154A are in communication with each other.

[0048] As shown in Figure 13, the intermediate oil passage forming members 150 and 150 are installed such that they are sandwiched between the chain cover 4 and the cylinder head 3, i.e., such that the mounting surfaces 152A and 152A abut against the contact surfaces 14 and 14 of the chain cover 4 through gaskets G and G and the protruding shaft sections 154 and 154 enter coaxially into the open sections 33 and 33 formed in the vane rotors 32 and 32 of the phase changing mechanisms 30 and 30. Meanwhile, the tip end faces of protruding sections 3A and 3A formed on the cylinder head 3 become abutted against the contact surface sections 14 and 14 of the chain cover 4 through seal members 58 and 58. Thus, when the intermediate oil passage forming members 150 and 150 are installed so as to be sandwiched between the chain cover 4 and the cylinder head 3, the communication passages 153a and 153a of the intermediate oil passage forming members 150 and 150 connect to the through passages 15a and 15a of the chain cover 4, the communication passages 153b and 153b of the intermediate oil passage forming members 150 and 150 connect to the through passages 15c and 15c of the chain cover 4, the oil passage openings 3a and 3a formed in the protruding sections 3A and 3A connect to the through passages 15b and 15b, the intra-shaft oil passages 154a and 154a connect to the advancement chambers 38A and 38A through the annular grooves 154A and 154A and the through passages 33A and 33A, and the intra-shaft oil passages 154b and 154b connect to the retardation chambers 38B and 38B through the through passages 33B and 33B. Oil passages 3b and 3b are formed in the protruding sections 3A and 3A, respectively, and serve to connect the oil passage openings 3a and 3a to internal block oil passages (not shown) formed inside the cylinder block 5 to convey hydraulic oil pumped from the oil pump 16. Oil filters 57 and 57 are housed in portions of the oil passages 3b and 3b nearer to the oil passage openings 3a and 3a, respectively.

[0049] After hydraulic oil pumped from the oil pump 16 flows into the internal block oil passage (not shown) formed inside the cylinder block, the hydraulic oil is conveyed from the oil passage openings 3a and 3a to the valve chambers 12 and 12 by the through passages 15b and 15b. Depending on the positions of the oil passage selecting control valves 18 and 18, the hydraulic oil then flows either through the through passages 15a and 15a, the communication passages 153a and 153a, and the oil passages 152a and 152a or through the through passages 15c and 15c, the communication passages 153c and 153c, and the oil passages 152b and 152b. If the hydraulic oil flows through the oil passages 152a and 152a, then it passes through the intra-shaft oil passages 154a and

154a, the annular grooves 154A and 154A, the through passages 33A and 33A, and into the advancement chambers 38A and 38A. Meanwhile, if the hydraulic oil flows through the oil passages 152b and 152b, then the hydraulic oil passes through the intra-shaft oil passages 154b and 154b, the through passages 33B and 33B, and into the retardation chambers 38B and 38B.

[0050] Similarly to the valve timing control apparatus 20 according to the first embodiment, this variation of the valve timing control apparatus enables the oil passage structure to be established easily while ensuring that the chain cover has sufficient strength.

[0051] In the valve timing control apparatus 20 according to the first embodiment, the communication passages 53a and 53b and the oil passages 52a and 52b serving to convey hydraulic oil flowing out of each of the valve chambers 12 to the intra-shaft oil passages 54a and 54b of the respective intermediate oil passage forming member 50 are formed in the intermediate oil passage forming member 50. However, it is also acceptable to form the oil passages conveying the hydraulic oil to the intra-shaft oil passages 54a and 54b with the intermediate oil passage member and the chain cover.

[0052] Figure 14 is an enlarged view showing contact surface sections 214 and 214 of a chain cover 204, Figure 15 is a perspective view showing the shape of a mounting surface 252A of an intermediate oil passage forming member 250, and Figure 16 cross sectional view showing an oil passage configuration. As shown in Figure 14, three through passages 215a, 215b, and 215c connecting to one of the valve chambers 212 and 212 are formed in each of the contact surface sections 214 and 214 of the chain cover 204. An oil groove 217a connecting to the through passage 215a and an oil groove 217c connecting to the through passage 215c are also formed in the contact surface sections 214 and 214. The oil grooves 217a and 217c extend substantially linearly from the through passages 215a and 215c to an upper end of the chain cover 204. In this embodiment, the oil passages are formed by covering the oil grooves 217a and 217c formed in the chain cover 204 with the intermediate oil passage forming member 250. In this way, the oil passages can be formed easily by simply forming grooves in the chain cover.

[0053] As shown in Figure 15, the intermediate oil passage forming members 250 are basically the same as the intermediate oil passage forming members 50 of the first embodiment except that the intermediate oil passage forming members 250 do not have communication passages 53a and 53b or intra-shaft oil passages 52a and 52b and the mounting surface 52A has been changed to the mounting surface 252A. Thus, each of the intermediate oil passage forming members 250 comprises a base section 252 having substantially the shape of an isosceles triangle in a frontal view, a protruding shaft section 254 that protrudes from a vertex portion of the base section 252 at a substantially right angle with respect to the base section 252, and a protruding shaft section 256

that protrudes from a position near a bottom side of the base section 252 (corresponding to a base of the triangle) at a substantially right angle with respect to the base section 252 in the same direction as the protruding shaft section 254. A mounting surface 252A that has been machined to a flat planar surface across its entire surface is provided on the opposite side of the base section 252 as the side on which the protruding shaft sections 254 and 256 are formed. Two intra-shaft oil passages 254a and 254b are formed in the protruding shaft section 254 such that they pass from a tip end face of the protruding shaft section 254 to the mounting surface 252A, and an intra-shaft oil passage 256a is formed in the protruding shaft section 256 such that it passes from a tip end face of the protruding shaft section 256 to the mounting surface 252A. An internal diameter of the intra-shaft oil passage 256a changes in a step-like fashion at an intermediate position along its length such that an enlarged diameter section 256a' having a larger internal diameter exists closer to the mounting surface 252A and a smaller diameter section exists closer to the tip end of the protruding shaft section 256. The enlarged diameter section 256a' houses an oil filter 257 serving to filter impurities contained in the hydraulic oil.

[0054] As shown in Figure 16, the intermediate oil passage forming members 250 and 250 are mounted to the chain cover 4 with the mounting surfaces 252A and 252A abutted against the contact surface sections 214 and 214 of the chain cover 4 through metal gaskets G and G and are fastened to the chain cover 4 with three bolts each. The pair of oil grooves 217a and 217c formed in each of the contact surface sections 214 and 214 are covered by the mounting surfaces 252A and 252A through the metal gaskets G and G so as to form oil passages. The oil passage formed by the oil groove 217a connects to the through passage 215a at one end and to the intra-shaft oil passage 254a at the other end, and the oil passage formed by the oil groove 217c connects to the through passages 215c at one end and to the intra-shaft oil passage 254b at the other end. Also, the intra-shaft oil passages 256a and 256a of the intermediate oil passage forming member 250 and 250 are connected to the respective through passages 215b and 215b of the chain cover 4. When the chain cover 4 is attached to the cylinder head 3 such that it covers the chain chamber 4A, the intermediate oil passage forming members 250 and 250 are arranged between the chain cover 4 and the cylinder head 3 and the protruding shaft sections 254 and 254 of the intermediate oil passage forming members 250 and 250 are inserted in a coaxial manner into the open sections 33 and 33 formed in the vane rotors 32 and 32 of the phase changing mechanisms 30 and 30. Also, the tip end faces of the protruding shaft sections 256 and 256 of the intermediate oil passage forming members 250 and 250 abut against the cylinder head 3 through seal members 58 and 58. Thus, at the tip end of each of the protruding shaft sections 254 and 254 of the intermediate oil passage forming members 250 and 250, the

intra-shaft oil passage 254a is connected to the advancement chamber 38A through the through passage 33A of each of the phase changing mechanisms 30 and 30, and the intra-shaft oil passage 254b is connected to the retardation chamber 38B through the through passage 33B of each of the phase changing mechanisms 30 and 30. Meanwhile, at the tip ends of the protruding shaft sections 256 and 256 of the intermediate oil passage forming members 250 and 250, the intra-shaft oil passages 256a and 256a are connected to oil passage openings 3a and 3a, respectively, formed in the cylinder head 3.

[0055] Hydraulic oil pumped by the oil pump 16 flows through an internal block oil passage (not shown) formed inside a cylinder block, through the oil passage openings 3a and 3a, and into the intra-shaft oil passages 256a and 256a inside the protruding shaft sections 256 and 256 of the intermediate oil passage forming members 250 and 250. The hydraulic oil flowing into the intra-shaft oil passages 256a and 256a is conveyed to the valve chambers 212 and 212 through the through passages 215b and 215b and then, depending on the positions of the oil passage selecting control valves 18 and 18, flows either through the through passages 215a and 215a and the oil grooves 217a and 217a or through the through passages 215c and 215c and the oil grooves 217c and 217c. If the hydraulic oil flows through the oil grooves 217a and 217a, then it passes through the intra-shaft oil passages 254a and 254a, the annular grooves 254A and 254A, the through passages 33A and 33A, and into the advancement chambers 38A and 38A. Meanwhile, if the hydraulic oil flows through the oil grooves 217c and 217c, then the hydraulic oil passes through the intra-shaft oil passages 254b and 254b, the through passages 33B and 33B, and into the retardation chambers 38B and 38B.

[0056] Similarly to the valve timing control apparatus 20 according to the first embodiment, this variation of the valve timing control apparatus enables the oil passage structure to be established easily while ensuring that the chain cover has sufficient strength.

[0057] In the valve timing control apparatuses 20 according to the first embodiment, the filter 57 or 257 is arranged in the enlarged diameter section 56a' or 256a' of the intra-shaft oil passage 56a and 256a of the protruding shaft sections 56 and 256 or inside the oil passage 3b of the protruding section 3A. However, it is acceptable to house the filter anywhere along the oil passages leading to the advancement chamber 38A and the retardation chamber 38B. For example, a filter can be arranged inside a communication passage 53a, 53b, 153a, 153b, a through passage 15a, 15b, 215a, 215b or 215b, an intra-shaft oil passage 54a, 54b, 154a, 154b, 254a, or 254b, or an oil passage opening 3a, or filters can be arranged in all of these.

SECOND EMBODIMENT

[0058] An internal combustion engine 301 equipped with a valve timing control apparatus 320 according to a

second embodiment of the present invention will now be explained. The internal combustion engine 301 equipped with a valve timing control apparatus 320 according to the second embodiment is basically the same as the internal combustion engine 1 equipped with the valve timing control apparatus 20 according to the first embodiment except that the chain cover 4 has been changed to a chain cover 304 and the intermediate oil passage forming members 50 have been changed to intermediate oil passage forming members 350. Therefore, only the portions of the internal combustion engine 301 equipped with a valve timing control apparatus 320 according to the second embodiment that are different from the valve timing control apparatus 20 according to the first embodiment will be explained. When necessary, portions having the same constituent features as the valve timing control apparatus 20 according to the first embodiment will be explained using constituent features of the valve timing control apparatus 20 according to the first embodiment (e.g., Figures 2 and 3 will be used to explain the phase changing mechanisms 30 and 30).

[0059] Figure 17 is a schematic view showing constituent features of an internal combustion engine 301 equipped with a valve timing control apparatus 320 according to an embodiment to the present invention. As shown in Figure 17, the valve timing control apparatus 320 of this embodiment is an apparatus contrived to change the open and close timings of the intake valves and exhaust valves (not shown) of an internal combustion engine 301 in which the intake valves and exhaust valves are opened and closed by rotating an intake camshaft 8 and an exhaust camshaft 10 using a timing chain 6. The timing chain 6 is arranged inside a chain chamber 304A covered by a chain cover 304 and serves to transmit rotation of a crankshaft 2 to the intake camshaft 8 and the exhaust camshaft 10. The valve timing control apparatus 320 comprises phase changing mechanisms 30 and 30 arranged on one end of each of the intake camshaft 8 and the exhaust camshaft 10, valve chambers 312 and 312 formed integrally on an engine mount section M of the chain cover 304, oil passage selecting control valves 18 and 18 that are inserted into the valve chambers 312 and 312, and intermediate oil passage forming members 350 that are attached to the chain cover 304 and serve to form oil passages between the valve chambers 312 and 312 and the phase changing mechanisms 33 and 33. **[0060]** Figure 18 is an enlarged view showing forward contact surface sections 314 of the chain cover 304. As shown in the figure, the valve chambers 312 and 312 are formed on a portion of the chain cover 304 where the engine mount section M is formed and have the form of generally cylindrical bottomed holes that open to the left and right with respect to the engine mount section M (left and right from the perspective of Figure 18). A forward contact surface section 314 having generally the shape of an upside-down U in a frontal view is formed on an upper portion of a forward face of the chain cover 304. More specifically, the U-shape has two leg sections 314A

and 314A and a connecting section 314B and is arranged to open downward (i.e., the connecting section 314B is arranged upward). The contact surface is machined in a planar fashion such that the heights of the forward contact surface section 314 are uniform. Through passages 315a and 315c that run to each of the valve chambers 312 and 312 and a seal ring groove 315d that surrounds an outer perimeter of the through passages 315a and 315c are formed in each of the leg sections 314A and 314A in positions near the open side of the U-shape, i.e., near the tip ends of the leg sections 314A and 314A. Through passages 315b and 315b running from a rearward face to the each the valve chambers 312 or 312, respectively, are formed in positions corresponding to the spaces between the respective pairs of through passages 315a and 315c. Rearward contact surface sections 316 and 316 machined to planar surfaces are provided around the peripheries of the through passages 315b and 315b on a rearward face of the chain cover 304. Openings 317 and 317 are formed at the intersecting portions where the connecting section 314B intersects each of the two leg sections 314A and 314A and a seal ring groove 319 is formed around a perimeter of each of the openings 317 and 317. In addition to the through passages 315a, 315a, 315c, and 315c and the openings 317 and 317, four bolt holes 314b, 314b, 314b, and 314b are formed in the forward contact surface section 314.

[0061] Figure 19 is an external perspective view showing an external appearance of an intermediate oil passage forming member 350, Figure 20 is a side view of the intermediate oil passage forming member 350, Figure 21 is a frontal view of the intermediate oil passage forming member 350. As shown in Figures 19, 20, and 21, the intermediate oil passage forming member 350 comprises a base section 352 and protruding shaft sections 354 and 354. The base section 352 has generally the shape of an upside-down U that is made up of two leg sections 352A and 352A and a connecting section 352B and arranged to open downward. The protruding shaft sections 354 and 354 are formed on the base section 352 at intersecting portions where the connecting section 352B intersects the two leg sections 352A and 352A and each is configured to protrude at a substantially right angle with respect to the base section 352.

[0062] Two oil passages 352a and 352b are bored into each of the leg sections 352A and 352A of the base section 352 such that they run from tip end portions of the leg sections 352A and 352A (i.e., the ends corresponding to the open end of the U-shape) to portions where the protruding shaft sections 354 and 354 are formed. Two pairs of communication passages 353a and 353b are bored from a mounting surface 352C side, i.e., the side on which the protruding shaft sections 354 and 354 are formed, such that they communicate with the two pairs of oil passages 352a and 352b, respectively. Each of the two oil passages 352a and the two oil passages 352b is plugged with a blind plug (not shown) at the tip ends of the two leg sections 352A and 352A, and the mounting

surface 352C is machined to be a flat planar surface. Four bosses B, B, B, and B each having a bolt hole formed therein are provided on the base section 352.

[0063] Two pairs of intra-shaft oil passages 354a and 354b are formed the protruding shaft sections 354 and 354, respectively, such that they run from tip end surfaces of the protruding shaft sections 354 and 354 and communicate with the two pairs of oil passages 352a and 352b, respectively, formed inside the base section 352. 5 As shown in Figure 20, an annular oil passage 354A is formed in an external circumferential surface of each of the protruding shaft sections 354 and 354 in a position closer to the tip end face. Two seal ring grooves SG1' and SG2' are formed in positions even closer to the tip end face than the annular groove 354A, and a seal ring groove SG3' is formed in a position closer to the base section 352 than the annular groove 354A. A notched section (not shown) is formed in each of the annular grooves 354A and 354A by cutting away an external circumferential surface corresponding to approximately 1/3 of the circumferential length of the annular groove 354A such that the intra-shaft oil passages 354a and 354a and the annular grooves 354A and 354A are in communication with each other. 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 2255 2260 2265 2270 2275 2280 2285 2290 2295 2300 2305 2310 2315 2320 2325 2330 2335 2340 2345 2350 2355 2360 2365 2370 2375 2380 2385 2390 2395 2400 2405 2410 2415 2420 2425 2430 2435 2440 2445 2450 2455 2460 2465 2470 2475 2480 2485 2490 2495 2500 2505 2510 2515 2520 2525 2530 2535 2540 2545 2550 2555 2560 2565 2570 2575 2580 2585 2590 2595 2600 2605 2610 2615 2620 2625 2630 2635 2640 2645 2650 2655 2660 2665 2670 2675 2680 2685 2690 2695 2700 2705 2710 2715 2720 2725 2730 2735 2740 2745 2750 2755 2760 2765 2770 2775 2780 2785 2790 2795 2800 2805 2810 2815 2820 2825 2830 2835 2840 2845 2850 2855 2860 2865 2870 2875 2880 2885 2890 2895 2900 2905 2910 2915 2920 2925 2930 2935 2940 2945 2950 2955 2960 2965 2970 2975 2980 2985 2990 2995 3000 3005 3010 3015 3020 3025 3030 3035 3040 3045 3050 3055 3060 3065 3070 3075 3080 3085 3090 3095 3100 3105 3110 3115 3120 3125 3130 3135 3140 3145 3150 3155 3160 3165 3170 3175 3180 3185 3190 3195 3200 3205 3210 3215 3220 3225 3230 3235 3240 3245 3250 3255 3260 3265 3270 3275 3280 3285 3290 3295 3300 3305 3310 3315 3320 3325 3330 3335 3340 3345 3350 3355 3360 3365 3370 3375 3380 3385 3390 3395 3400 3405 3410 3415 3420 3425 3430 3435 3440 3445 3450 3455 3460 3465 3470 3475 3480 3485 3490 3495 3500 3505 3510 3515 3520 3525 3530 3535 3540 3545 3550 3555 3560 3565 3570 3575 3580 3585 3590 3595 3600 3605 3610 3615 3620 3625 3630 3635 3640 3645 3650 3655 3660 3665 3670 3675 3680 3685 3690 3695 3700 3705 3710 3715 3720 3725 3730 3735 3740 3745 3750 3755 3760 3765 3770 3775 3780 3785 3790 3795 3800 3805 3810 3815 3820 3825 3830 3835 3840 3845 3850 3855 3860 3865 3870 3875 3880 3885 3890 3895 3900 3905 3910 3915 3920 3925 3930 3935 3940 3945 3950 3955 3960 3965 3970 3975 3980 3985 3990 3995 4000 4005 4010 4015 4020 4025 4030 4035 4040 4045 4050 4055 4060 4065 4070 4075 4080 4085 4090 4095 4100 4105 4110 4115 4120 4125 4130 4135 4140 4145 4150 4155 4160 4165 4170 4175 4180 4185 4190 4195 4200 4205 4210 4215 4220 4225 4230 4235 4240 4245 4250 4255 4260 4265 4270 4275 4280 4285 4290 4295 4300 4305 4310 4315 4320 4325 4330 4335 4340 4345 4350 4355 4360 4365 4370 4375 4380 4385 4390 4395 4400 4405 4410 4415 4420 4425 4430 4435 4440 4445 4450 4455 4460 4465 4470 4475 4480 4485 4490 4495 4500 4505 4510 4515 4520 4525 4530 4535 4540 4545 4550 4555 4560 4565 4570 4575 4580 4585 4590 4595 4600 4605 4610 4615 4620 4625 4630 4635 4640 4645 4650 4655 4660 4665 4670 4675 4680 4685 4690 4695 4700 4705 4710 4715 4720 4725 4730 4735 4740 4745 4750 4755 4760 4765 4770 4775 4780 4785 4790 4795 4800 4805 4810 4815 4820 4825 4830 4835 4840 4845 4850 4855 4860 4865 4870 4875 4880 4885 4890 4895 4900 4905 4910 4915 4920 4925 4930 4935 4940 4945 4950 4955 4960 4965 4970 4975 4980 4985 4990 4995 5000 5005 5010 5015 5020 5025 5030 5035 5040 5045 5050 5055 5060 5065 5070 5075 5080 5085 5090 5095 5100 5105 5110 5115 5120 5125 5130 5135 5140 5145 5150 5155 5160 5165 5170 5175 5180 5185 5190 5195 5200 5205 5210 5215 5220 5225 5230 5235 5240 5245 5250 5255 5260 5265 5270 5275 5280 5285 5290 5295 5300 5305 5310 5315 5320 5325 5330 5335 5340 5345 5350 5355 5360 5365 5370 5375 5380 5385 5390 5395 5400 5405 5410 5415 5420 5425 5430 5435 5440 5445 5450 5455 5460 5465 5470 5475 5480 5485 5490 5495 5500 5505 5510 5515 5520 5525 5530 5535 5540 5545 5550 5555 5560 5565 5570 5575 5580 5585 5590 5595 5600 5605 5610 5615 5620 5625 5630 5635 5640 5645 5650 5655 5660 5665 5670 5675 5680 5685 5690 5695 5700 5705 5710 5715 5720 5725 5730 5735 5740 5745 5750 5755 5760 5765 5770 5775 5780 5785 5790 5795 5800 5805 5810 5815 5820 5825 5830 5835 5840 5845 5850 5855 5860 5865 5870 5875 5880 5885 5890 5895 5900 5905 5910 5915 5920 5925 5930 5935 5940 5945 5950 5955 5960 5965 5970 5975 5980 5985 5990 5995 6000 6005 6010 6015 6020 6025 6030 6035 6040 6045 6050 6055 6060 6065 6070 6075 6080 6085 6090 6095 6100 6105 6110 6115 6120 6125 6130 6135 6140 6145 6150 6155 6160 6165 6170 6175 6180 6185 6190 6195 6200 6205 6210 6215 6220 6225 6230 6235 6240 6245 6250 6255 6260 6265 6270 6275 6280 6285 6290 6295 6300 6305 6310 6315 6320 6325 6330 6335 6340 6345 6350 6355 6360 6365 6370 6375 6380 6385 6390 6395 6400 6405 6410 6415 6420 6425 6430 6435 6440 6445 6450 6455 6460 6465 6470 6475 6480 6485 6490 6495 6500 6505 6510 6515 6520 6525 6530 6535 6540 6545 6550 6555 6560 6565 6570 6575 6580 6585 6590 6595 6600 6605 6610 6615 6620 6625 6630 6635 6640 6645 6650 6655 6660 6665 6670 6675 6680 6685 6690 6695 6700 6705 6710 6715 6720 6725 6730 6735 6740 6745 6750 6755 6760 6765 6770 6775 6780 6785 6790 6795 6800 6805 6810 6815 6820 6825 6830 6835 6840 6845 6850 6855 6860 6865 6870 6875 6880 6885 6890 6895 6900 6905 6910 6915 6920 6925 6930 6935 6940 6945 6950 6955 6960 6965 6970 6975 6980 6985 6990 6995 7000 7005 7010 7015 7020 7025 7030 7035 7040 7045 7050 7055 7060 7065 7070 7075 7080 7085 7090 7095 7100 7105 7110 7115 7120 7125 7130 7135 7140 7145 7150 7155 7160 7165 7170 7175 7180 7185 7190 7195 7200 7205 7210 7215 7220 7225 7230 7235 7240 7245 7250 7255 7260 7265 7270 7275 7280 7285 7290 7295 7300 7305 7310 7315 7320 7325 7330 7335 7340 7345 7350 7355 7360 7365 7370 7375 7380 7385 7390 7395 7400 7405 7410 7415 7420 7425 7430 7435 7440 7445 7450 7455 7460 7465 7470 7475 7480 7485 7490 7495 7500 7505 7510 7515 7520 7525 7530 7535 7540 7545 7550 7555 7560 7565 7570 7575 7580 7585 7590 7595 7600 7605 7610 7615 7620 7625 7630 7635 7640 7645 7650 7655 7660 7665 7670 7675 7680 7685 7690 7695 7700 7705 7710 7715 7720 7725 7730 7735 7740 7745 7750 7755 7760 7765 7770 7775 7780 7785 7790 7795 7800 7805 7810 7815 7820 7825 7830 7835 7840 7845 7850 7855 7860 7865 7870 7875 7880 7885 7890 7895 7900 7905 7910 7915 7920 7925 7930 7935 7940 7945 7950 7955 7960 7965 7970 7975 7980 7985 7990 7995 8000 8005 8010 8015 8020 8025 8030 8035 8040 8045 8050 8055 8060 8065 8070 8075 8080 8085 8090 8095 8100 8105 8110 8115 8120 8125 8130 8135 8140 8145 8150 8155 8160 8165 8170 8175 8180 8185 8190 8195 8200 8205 8210 8215 8220 8225 8230 8235 8240 8245 8250 8255 8260 8265 8270 8275 8280 8285 8290 8295 8300 8305 8310 8315 8320 8325 8330 8335 8340 8345 8350 8355 8360 8365 8370 8375 8380 8385 8390 8395 8400 8405 8410 8415 8420 8425 8430 8435 8440 8445 8450 8455 8460 8465 8470 8475 8480 8485 8490 8495 8500 8505 8510 8515 8520 8525 8530 8535 8540 8545 8550 8555 8560 8565 8570 8575 8580 8585 8590 8595 8600 8605 8610 8615 8620 8625 8630 8635 8640 8645 8650 8655 8660 8665 8670 8675 8680 8685 8690 8695 8700 8705 8710 8715 8720 8725 8730 8735 8740 8745 8750 8755 8760 8765 8770 8775 8780 8785 8790 8795 8800 8805 8810 8815 8820 8825 8830 8835 8840 8845 8850 8855 8860 8865 8870 8875 8880 8885 8890 8895 8900 8905 8910 8915 8920 8925 8930 8935 8940 8945 8950 8955 8960 8965 8970 8975 8980 8985 8990 8995 9000 9005 9010 9015 9020 9025 9030 9035 9040 9045 9050 9055 9060 9065 9070 9075 9080 9085 9090 9095 9100 9105 9110 9115 9120 9125 9130 9135 9140 9145 9150 9155 9160 9165 9170 9175 9180 9185 9190 9195 9200 9205 9210 9215 9220 9225 9230 9235 9240 9245 9250 9255 9260 9265 9270 9275 9280 9285 9290 9295 9300 9305 9310 9315 9320 9325 9330 9335 9340 9345 9350 9355 9360 9365 9370 9375 9380 9385 9390 9395 9400 9405 9410 9415 9420 9425 9430 9435 9440 9445 9450 9455 9460 9465 9470 9475 9480 9485 9490 9495 9500 9505 9510 9515 9520 9525 9530 9535 9540 9545 9550 9555 9560 9565 9570 9575 9580 9585 9590 9595 9600 9605 9610 9615 9620 9625 9630 9635 9640 9645 9650 9655 9660 9665 9670 9675 9680 9685 9690 9695 9700 9705 9710 9715 9720 9725 9730 9735 9740 9745 9750 9755 9760 9765 9770 9775 9780 9785 9790 9795 9800 9805 9810 981

truding shaft sections 354 and 354 of the intermediate oil passage forming member 350 are inserted in a coaxial manner into the open sections 33 and 33 formed in the vane rotors 32 and 32 of the phase changing mechanism 30 and 30, and the rearward contact surface sections 316 and 316 abut against the cylinder head 3. Thus, each of the two infra-shaft oil passages 354a of the intermediate oil passage forming member 350 is connected to and in communication with the advancement chamber 38A of the respective phase changing mechanism 30 or 30 through the respective through passage 33A, and each of the two intra-shaft oil passages 354b of the intermediate oil passage forming member 350 is connected to and in communication with the retardation chamber 38B of the respective phase changing mechanism 30 or 30 through the respective through passages 33B. Meanwhile, the through passages 315b and 315b are connected to oil passage openings 3a and 3a, respectively, formed in the cylinder head 3. The oil passage openings 3a and 3a communicate with an internal block oil passage (not shown) formed inside a cylinder block 5 through which hydraulic oil pumped by the oil pump 16 flows.

[0065] As shown in Figure 22, when the chain cover 4, to which the intermediate oil passage forming member 350 has been mounted, is attached to the cylinder head 3, hydraulic oil pumped from the oil pump 16 flows through the internal block oil passage (not shown) formed inside the cylinder block, through an oil passage formed inside the cylinder head, through the oil passage ports 3a and 3a, and into the through passages 315b and 315b formed in the rearward contact surface sections 316 and 316 formed on the chain cover 304. After flowing into the through passages 315b and 315b, the hydraulic oil is conveyed to the valve chambers 312 and 312 and then, depending on the positions of the oil passage selecting control valves 18 and 18, the hydraulic oil flows either through the through passages 315a and 315a, the communication passages 353a and 353a, and the oil passages 352a and 352a or through the through passages 315c and 315c, the communication passages 353c and 353c, and the oil passages 352b and 352b. If the hydraulic oil flows through the oil passages 352a and 352a, then it passes through the intra-shaft oil passages 354a and 354a, the annular grooves 354A and 354A, the through passages 33A and 33A, and into the advancement chambers 38A and 38A. Meanwhile, if the hydraulic oil flows through the oil passages 352b and 352b, then the hydraulic oil passes through the intra-shaft oil passages 354b and 354b, the through passages 33B and 33B, and into the retardation chambers 38B and 38B. When the hydraulic oil flows into the advancement chambers 38A and 38A or the retardation chambers 38B and 38B, the vane rotors 32 and 32 rotate relative to the housings 34 and 34 and change the open and close timings of the intake valves and the exhaust valves.

[0066] With the valve timing control apparatus 320 according to the second embodiment described above, machining of the oil passages can be accomplished more

easily because the valve chambers 312 and 312 into which the oil passage selecting valves 18 and 18 are installed are formed as integral portions of the chain cover 304 and the oil passages serving to convey hydraulic oil

5 from the valve chambers 312 and 312 to the advancement chambers 38A and 38A and the retardation chambers 38B and 38B (i.e., the two pairs of communication oil passages 353a and 353b, the two pairs of oil passages 352a and 352b, and the two pairs of intra-shaft oil passages 354a and 354b) are provided in an intermediate oil passage forming member 350 that is a separate entity from the chain cover 304. Moreover, since the openings 317 and 317 formed in the chain cover 304 in order to attach the intermediate oil passage forming member 350 to the chain cover 304 is much smaller than in a conventional apparatus, the degree to which the strength of the chain cover 4 declines can be suppressed. As a result, the oil passage structure can be easily established while ensuring that the chain cover 304 has sufficient strength.

10 **[0067]** With the valve timing control apparatuses 20 according to the first embodiment, the intermediate oil passage forming members 50 and 50, 150 and 150, or 250 and 250 are attached to the chain cover 4, 104 or 204 with bolts first and then the chain cover 4, 104 or 204

15 is attached to the cylinder head 3. However, it is also acceptable to configure the apparatus such that the intermediate oil passage forming members 50 and 50, 150 and 150, or 250 and 250 are attached to the cylinder head 3 with bolts first and then chain cover 4, 104 or 204

20 is attached to the cylinder head 3 such that it covers the intermediate oil passage forming members 50 and 50, 150 and 150, or 250 and 250.

[0068] In the valve timing control apparatuses 20 according to the first embodiment and the second embodiment, a phase change mechanism 30 is provided on one end of the intake camshaft 8 and another phase change mechanism 30 is provided on one end of the exhaust camshaft 10. However, it is also acceptable to provide a phase change mechanism 30 on one end of only the intake camshaft 8 or only the exhaust camshaft 10. In such a case, only one intermediate oil passage forming member 50, 150, 250, or 350 should be provided and one oil passage opening 3a should be formed in the cylinder head 3.

[0069] Although embodiments of the present invention are explained herein, the present invention is not limited to these embodiments. Various other embodiments can be conceived without departing from the scope of the invention.

[0070] When an internal combustion engine is equipped with a valve timing control apparatus according to any of the previously described embodiments, the internal combustion engine exhibits the same effects as a valve timing control apparatus according to the embodiments, e.g., the effect of enabling the oil passage structure to be established easily while ensuring that the chain cover has sufficient strength.

[0071] In the above described embodiments, the

through passages 15a, 215a, or 315a correspond to advancement ports of the valve chamber, the through passages 15b, 215b, or 315b correspond to inlet ports of the valve chamber, and the through passages 15c, 215c, or 315c correspond to retardation ports. Moreover, the oil passages 54a, 154a, 254a, or 354a correspond to advancement conveying passages, and the oil passages 54b, 154b, 254b, or 354b correspond to retardation conveying passages. The oil passages 52a, 152a, 252A and 217a, or 352a correspond to advancement connecting oil passages, and the oil passages 52b, 152b, 252B and 217b, or 352b correspond to retardation connecting oil passages.

GENERAL INTERPRETATION OF TERMS

[0072] In understanding the scope of the present invention, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "including", "having" and their derivatives. Also, the terms "part," "section," "portion," "member" or "element" when used in the singular can have the dual meaning of a single part or a plurality of parts. Also as used herein to describe the above embodiment(s), the following directional terms "forward", "rearward", "above", "downward", "vertical", "horizontal", "below" and "transverse" as well as any other similar directional terms refer to those directions of an engine when the engine is oriented as shown in Figure 1. Accordingly, these terms, as utilized to describe the present invention should be interpreted relative to a vehicle equipped with the engine.

[0073] While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. For example, the size, shape, location or orientation of the various components can be changed as needed and/or desired. Components that are shown directly connected or contacting each other can have intermediate structures disposed between them. The functions of one element can be performed by two, and vice versa. The structures and functions of one embodiment can be adopted in another embodiment. It is not necessary for all advantages to be present in a particular embodiment at the same time. Every feature which is unique from the prior art, alone or in combination with other features, also should be considered a separate description of further inventions by the applicant, including the structural and/or functional concepts embodied by such feature(s). Thus, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of

limiting the invention as defined by the appended claims and their equivalents.

5 Claims

1. A valve timing control apparatus for changing a relative rotational phase of a camshaft (8 or 10) with respect to a crankshaft (2) using a hydraulic pressure of a hydraulic oil supplied from an oil pump (16), the valve timing control apparatus comprising:

15 a chain cover (4, 204, 304) defining a valve chamber (12, 212, 312) having an inlet port (15b, 215b, 315b) for the hydraulic oil, an advancement port (15a, 215a, 315a), and a retardation port (15c, 215c, 315c);

20 a phase changing mechanism (30) coupled to an end portion of the camshaft (8 or 10) with the phase changing mechanism (30) being at least partially covered by the chain cover (4, 204, 304), the phase changing mechanism (30) having a plurality of hydraulic pressure chambers including an advancement chamber (38A) and a retardation chamber (38B);

25 a selector valve (18) housed in the valve chamber (12, 212, 312) of the chain cover (4, 204, 304), and configured and arranged to selectively open the advancement port (15a, 215a, 315a) or the retardation port (15c, 215c, 315c); and an intermediate oil passage forming member (50, 150, 250, 350) for conveying the hydraulic oil in the valve chamber (12, 212, 312) of the chain cover (4, 204, 304) from the advancement port (15a, 215a, 315a) of the valve chamber (12, 212, 312) to the advancement chamber (38A) of the phase changing mechanism (30), and from the retardation port (15c, 215c, 315c) of the valve chamber (12, 212, 312) to the retardation chamber (38B) of the phase changing mechanism (30).

30 2. The valve timing control apparatus recited in claim 1, wherein the intermediate oil passage forming member (50, 150, 250, 350) includes a shaft section (54, 154, 254, 354) inserted into the phase changing mechanism (30) so as to be coaxial with respect to the camshaft (8 or 10) and has an advancement conveying passage (54a, 154a, 254a, 354a) for conveying the hydraulic oil to the advancement chamber (38A) of the phase changing mechanism (30) and a retardation conveying passage (54b, 154b, 254b, 354b) for conveying the hydraulic oil to the retardation chamber (38B) the phase changing mechanism (30), and a connecting section (52, 152, 252, 352) forming an

advancement connecting oil passage (52a, 152a, 252A and 217a, 352a) that connects and communicates between the advancement port (15a, 215a, 315a) of the valve chamber (12, 212, 312) and the advancement conveying passage (54a, 154a, 254a, 354a), and a retardation connecting oil passage (52b, 152b, 252A and 217c, 352b) that connects and communicates between the retardation port (15c, 215c, 315c) of the valve chamber (12, 212, 312) and the retardation conveying passage (54b, 154b, 254b, 354b). 5

3. The valve timing control apparatus recited in claim 1 or 2, wherein the intermediate oil passage forming member (50, 150, 250) is attached to an inside of the chain cover (4, 204). 15

4. The valve timing control apparatus recited in claim 3, wherein the intermediate oil passage forming member (50, 250) includes a supply section (56, 256) having a supply passage (56a, 256a) for carrying the hydraulic oil supplied from the oil pump (16) to the inlet port (15b, 215b, 315b) of the valve chamber (12, 212, 312). 20

5. The valve timing control apparatus recited in claim 3 or 4, wherein the intermediate oil passage forming member (50, 250) includes a filter member (57, 257) arranged in the supply passage (56a, 256a) to filter impurities contained in the hydraulic oil. 25

6. The valve timing control apparatus recited in any one of claims 2 to 5, wherein the intermediate oil passage forming member (50, 150, 250, 350) includes a filter member arranged in the advancement conveying passage (54a, 154a, 254a, 354a) and the retardation conveying passage (54b, 154b, 254b, 354b) and/or the advancement connecting oil passage (52a, 152a, 252A and 217a, 352a) and the retardation connecting oil passage (52b, 152b, 252A and 217c, 352b) to filter impurities contained in the hydraulic oil. 30

7. The valve timing control apparatus recited in any one of claims 2 to 6, wherein the advancement connecting oil passage (52a, 152a, 352a) and the retardation connecting oil passage (52b, 152b, 352b) are formed within the connecting section (52, 152, 352). 35

8. The valve timing control apparatus recited in any one of claims 2 to 6, wherein the advancement connecting oil passage (252A and 217a) and the retardation connecting oil passage (252A and 217c) are formed by covering grooves (217a and 217c) formed in the chain cover (204) with the connecting section (252). 40

9. The valve timing control apparatus recited in claim 1 or 2, wherein the intermediate oil passage forming member (350) is attached to an outside of the chain cover (304). 45

10. An internal combustion engine that is provided with a variable valve timing control apparatus according to any one of claims 1 to 9 and configured such that the oil pump (16) is driven by rotation of a crankshaft (2) of the engine. 50

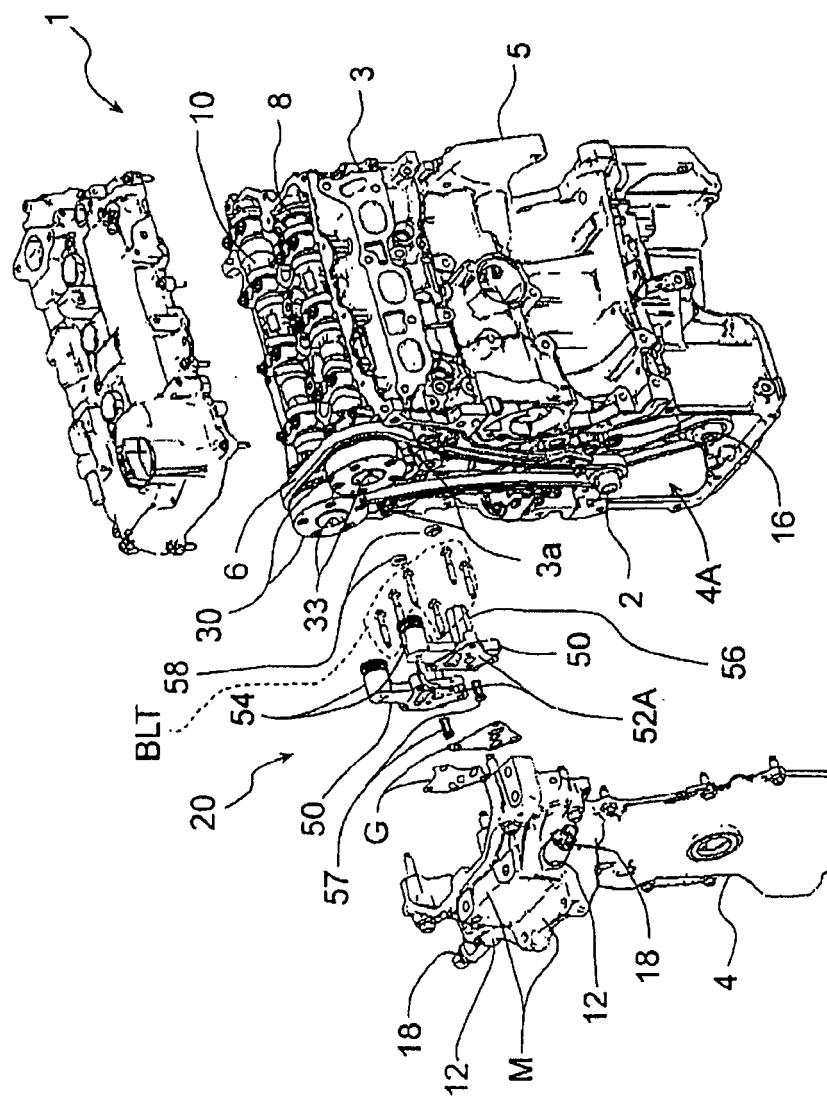


FIG. 1

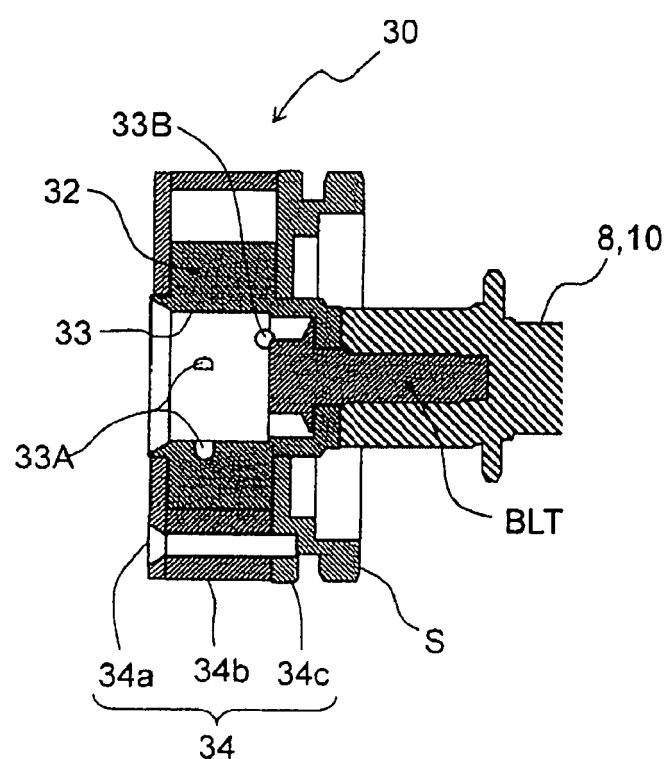


FIG. 2

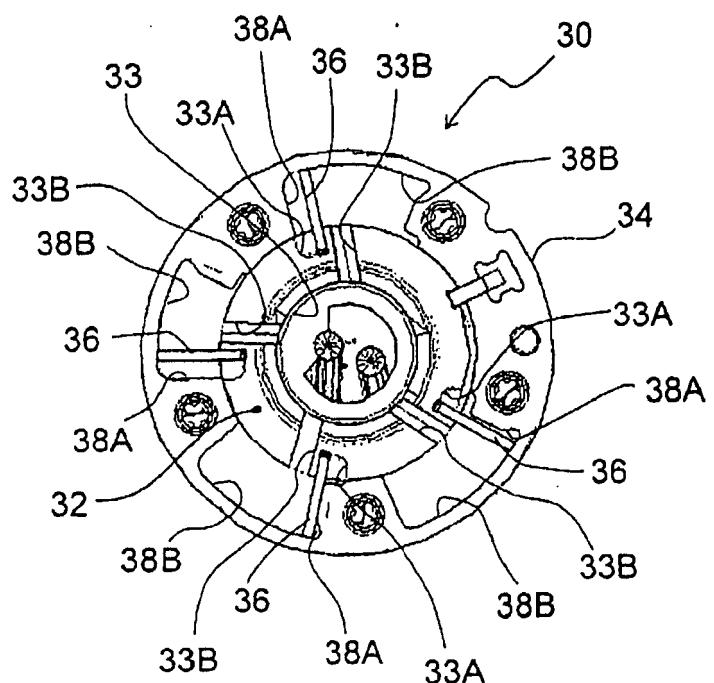


FIG. 3

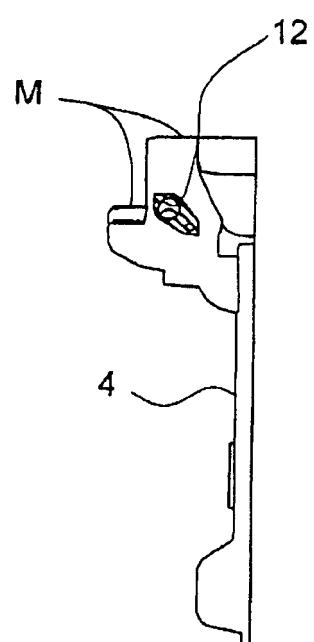


FIG. 4

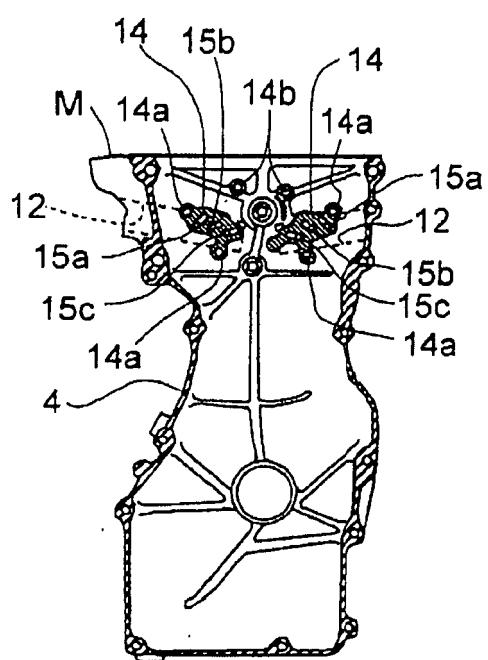


FIG. 5

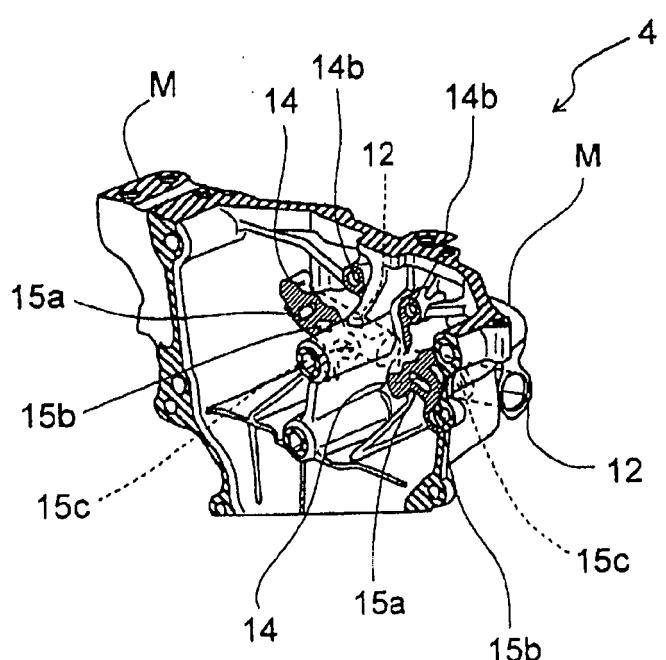


FIG. 6

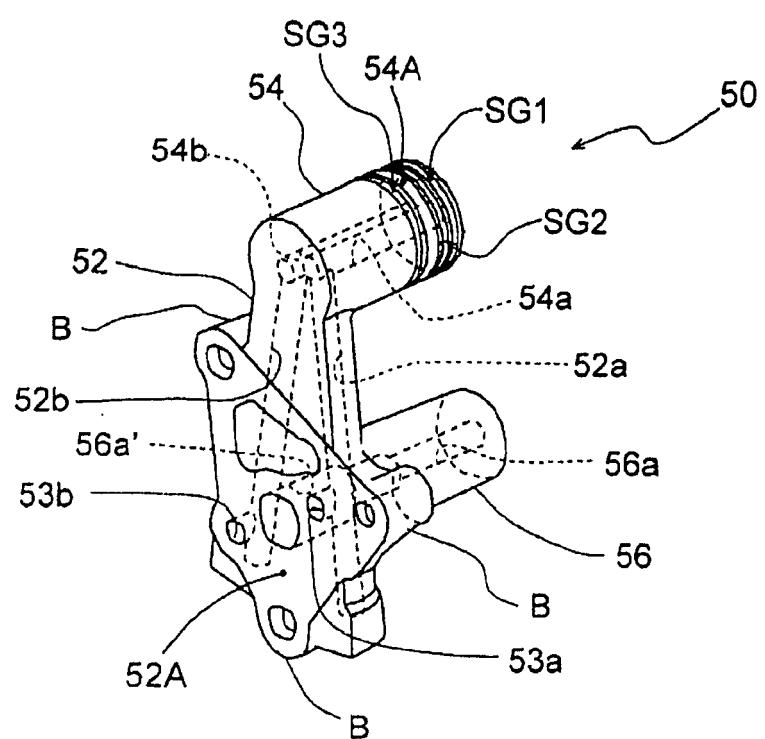


FIG. 7

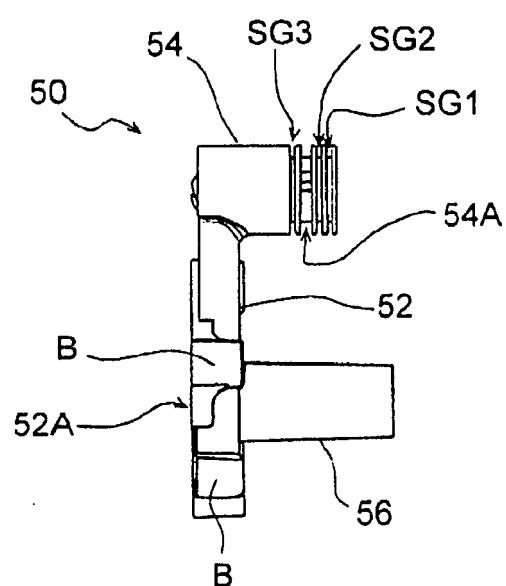


FIG. 8

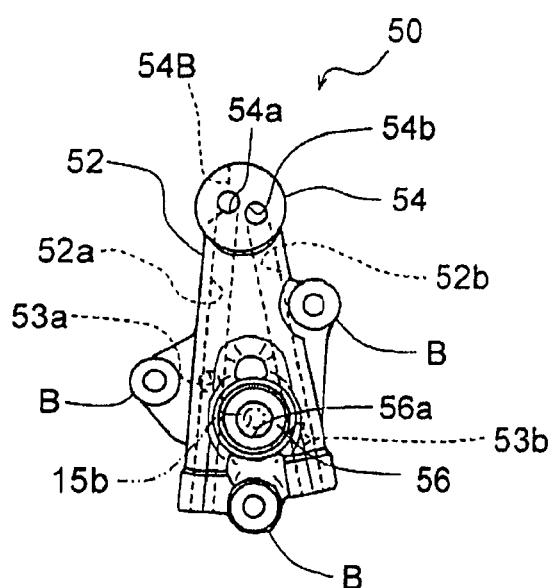


FIG. 9

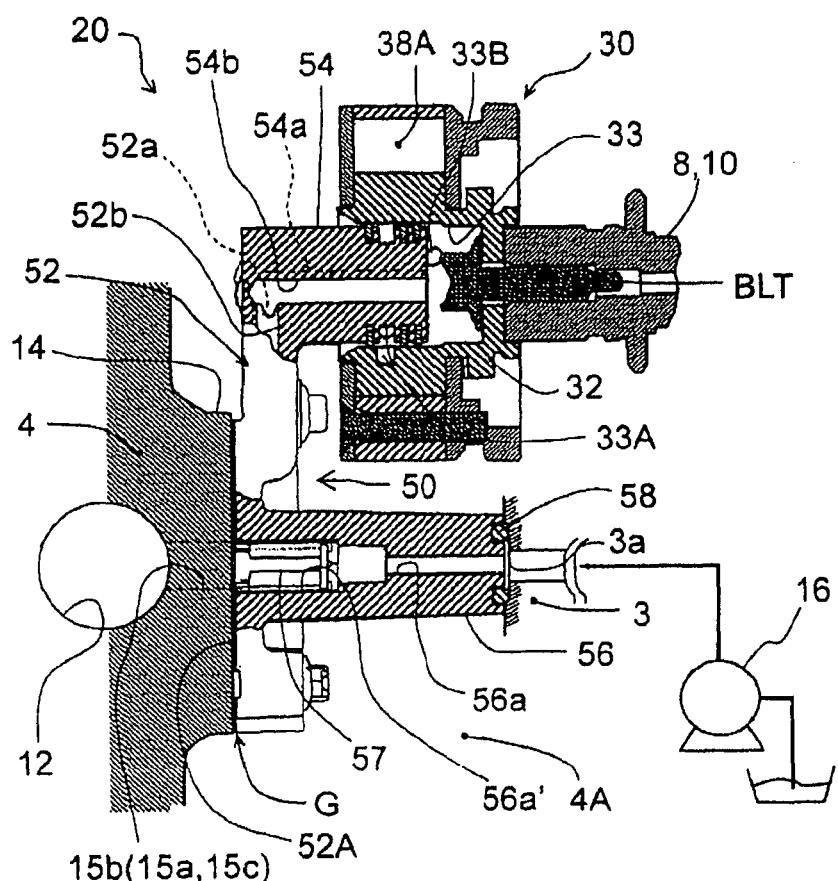


FIG. 10

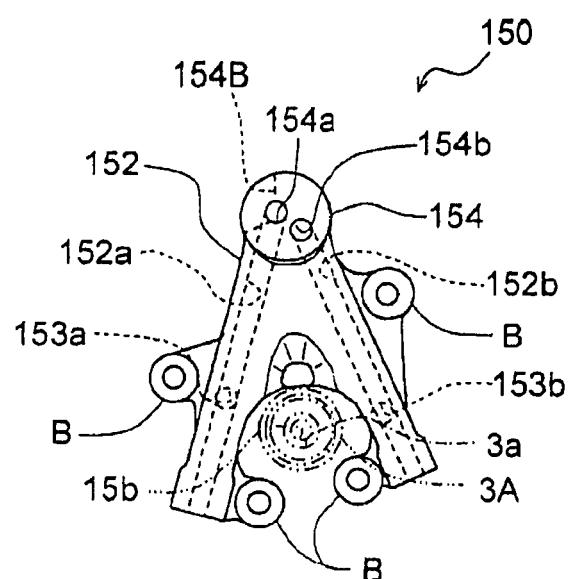


FIG. 11

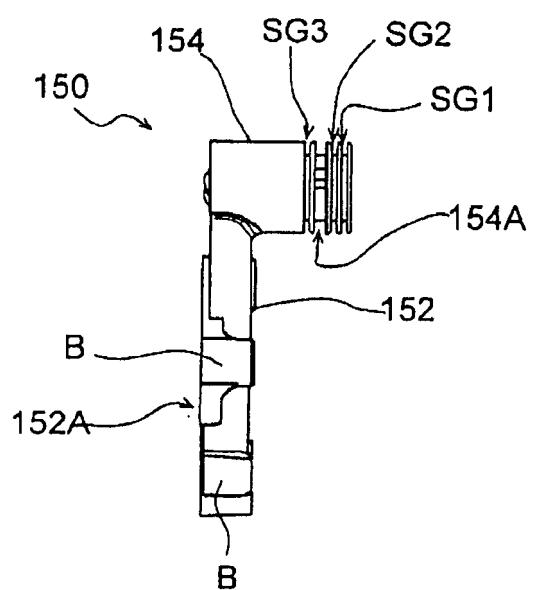


FIG. 12

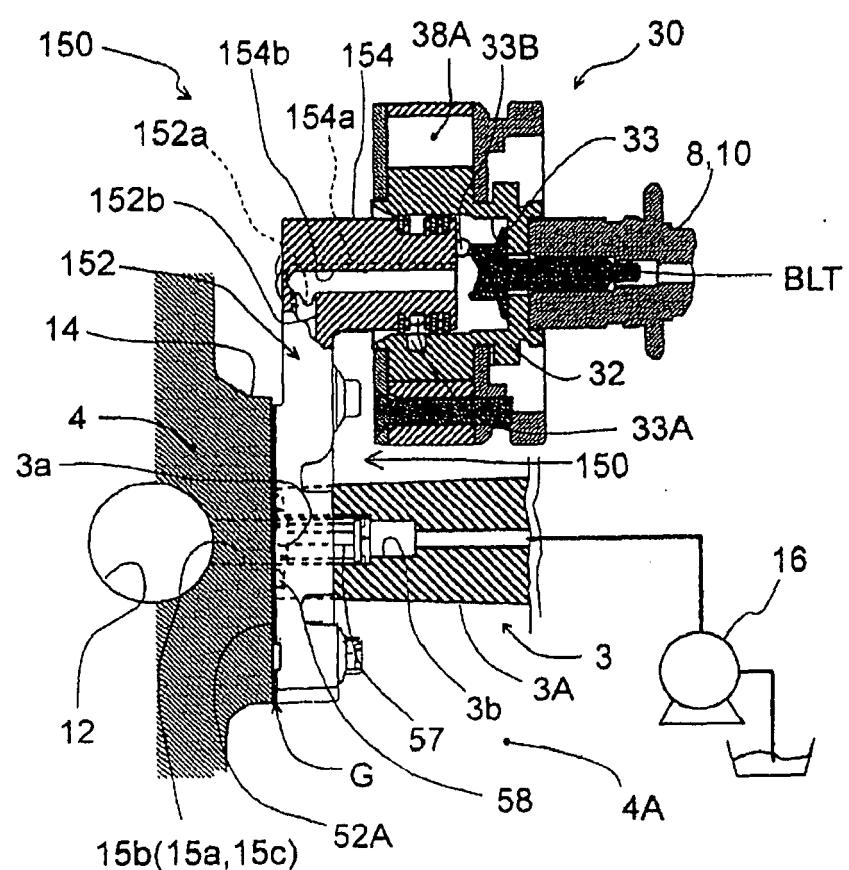


FIG. 13

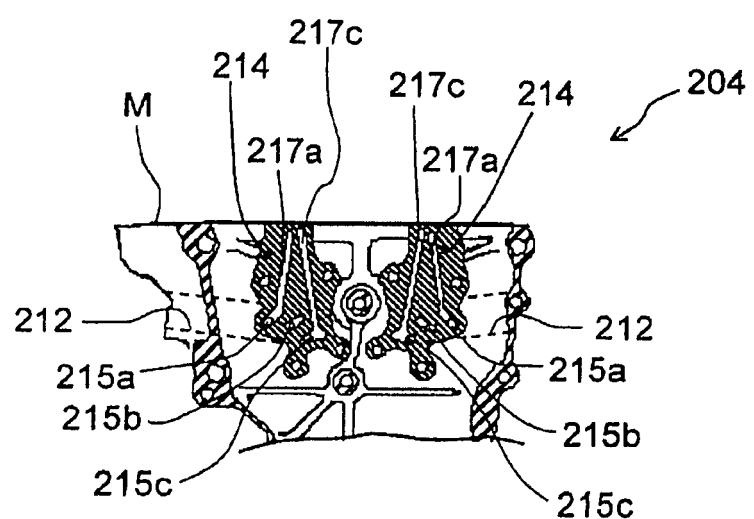


FIG. 14

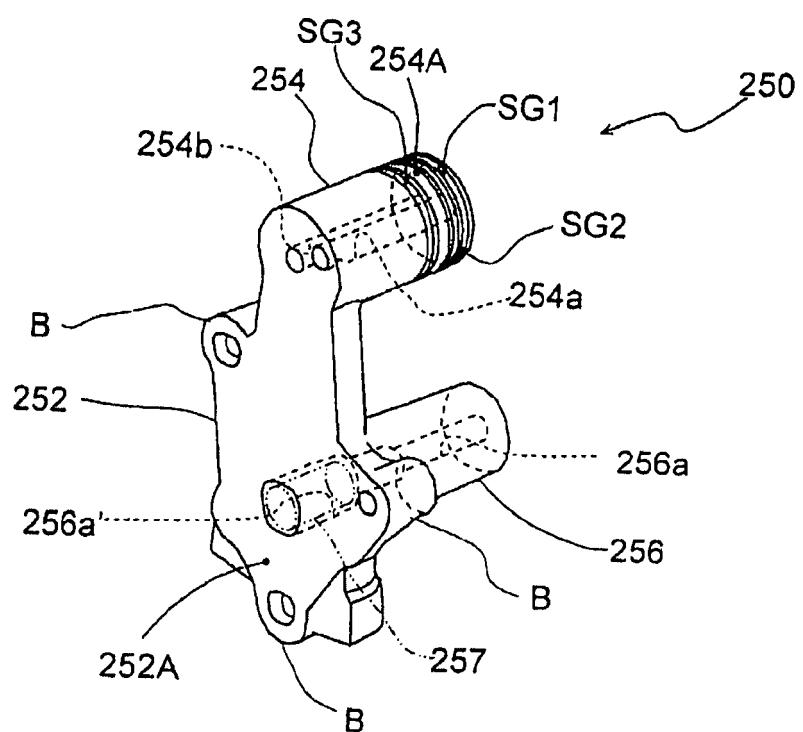


FIG. 15

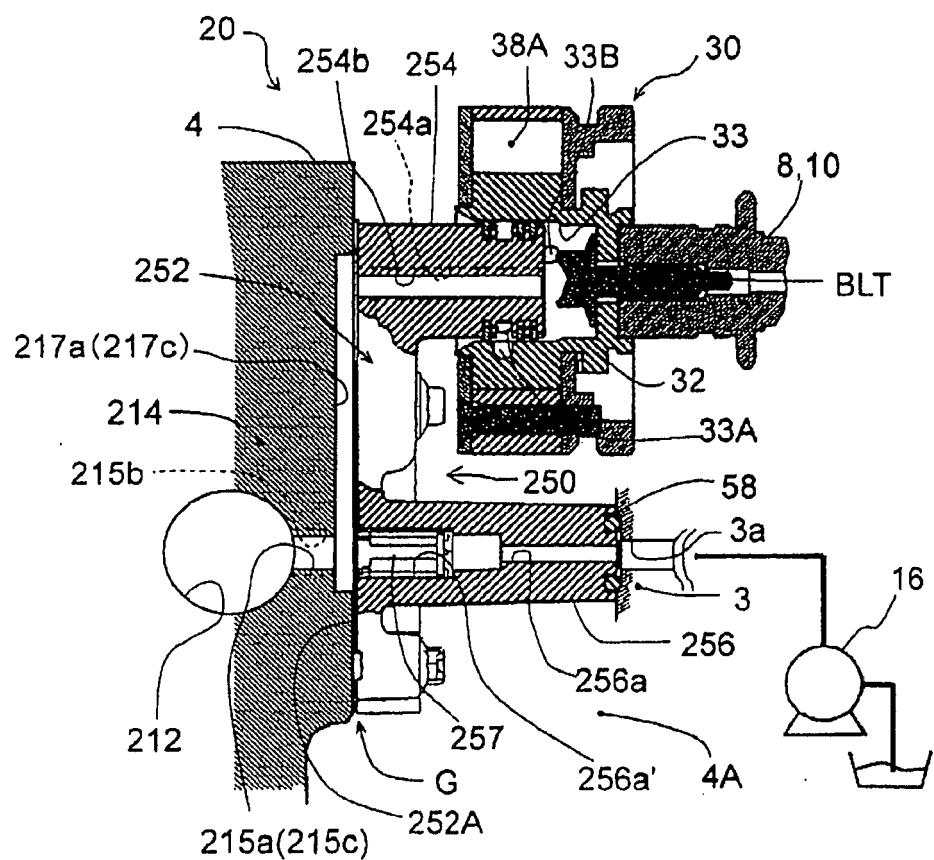


FIG. 16

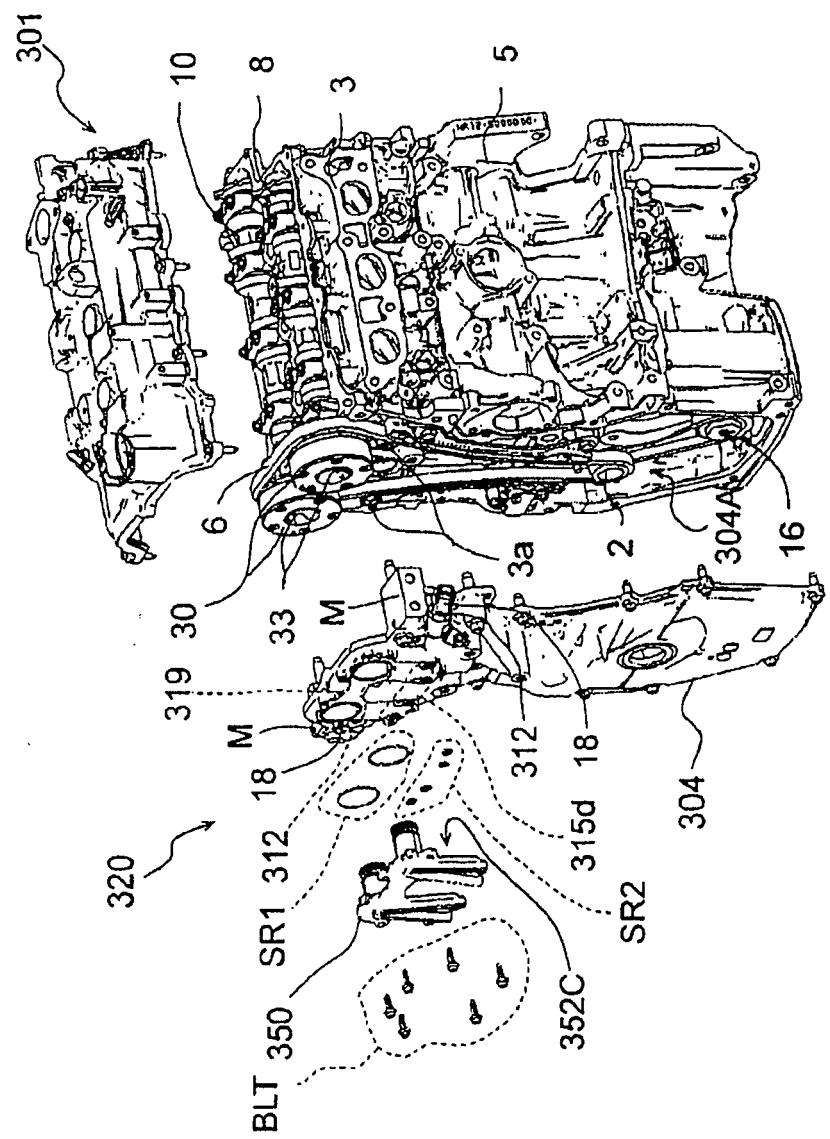


FIG. 17

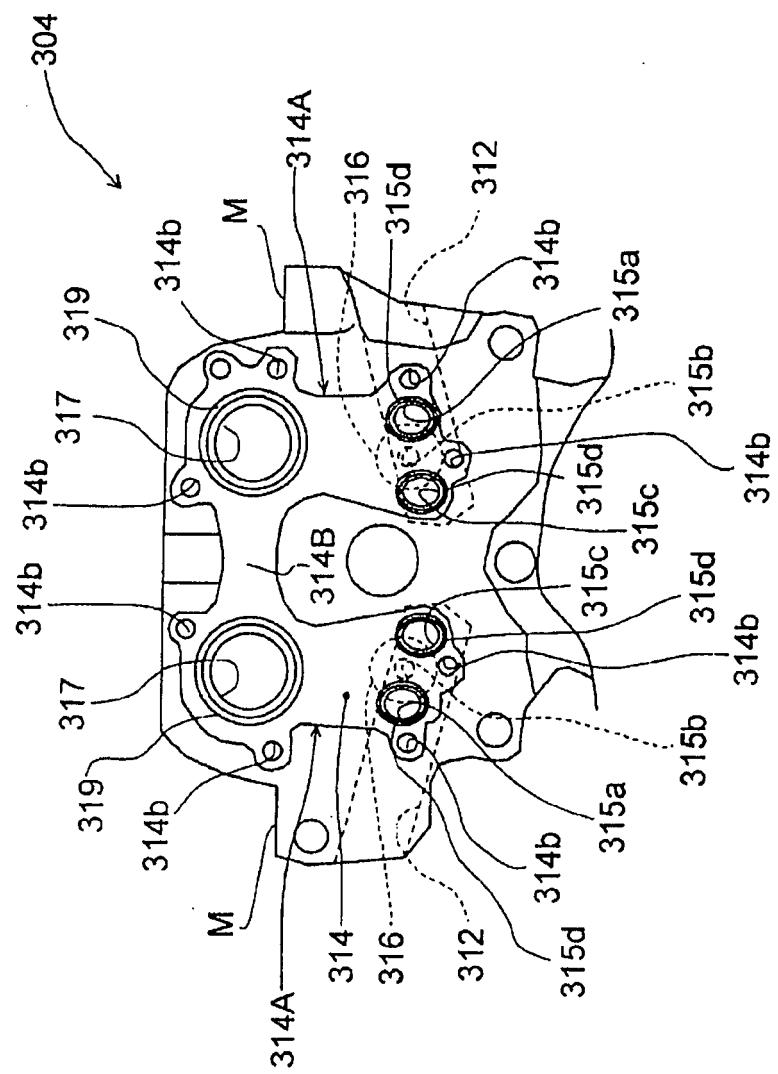


FIG. 18

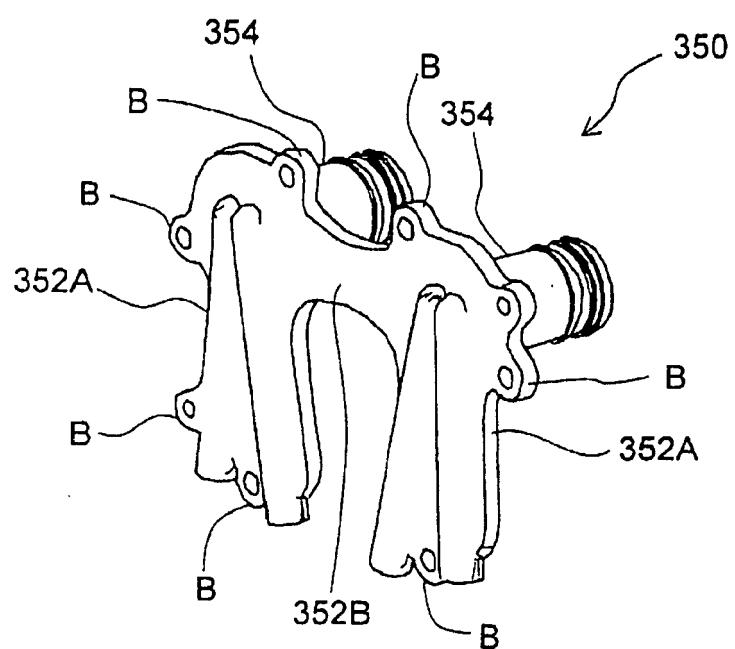
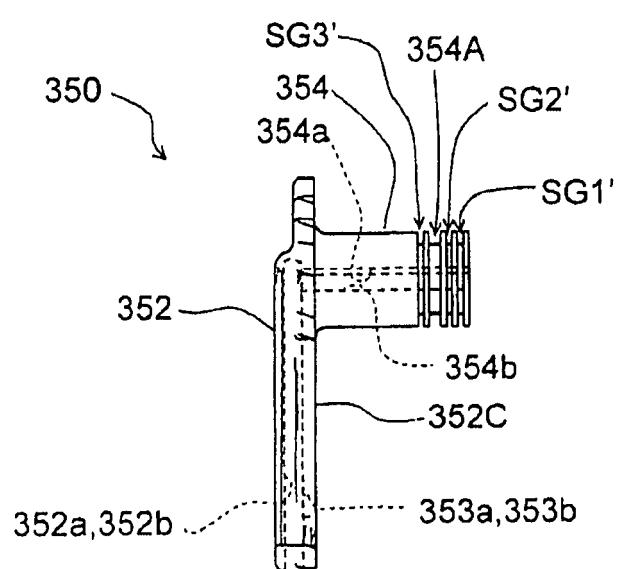


FIG. 19



F I G. 20

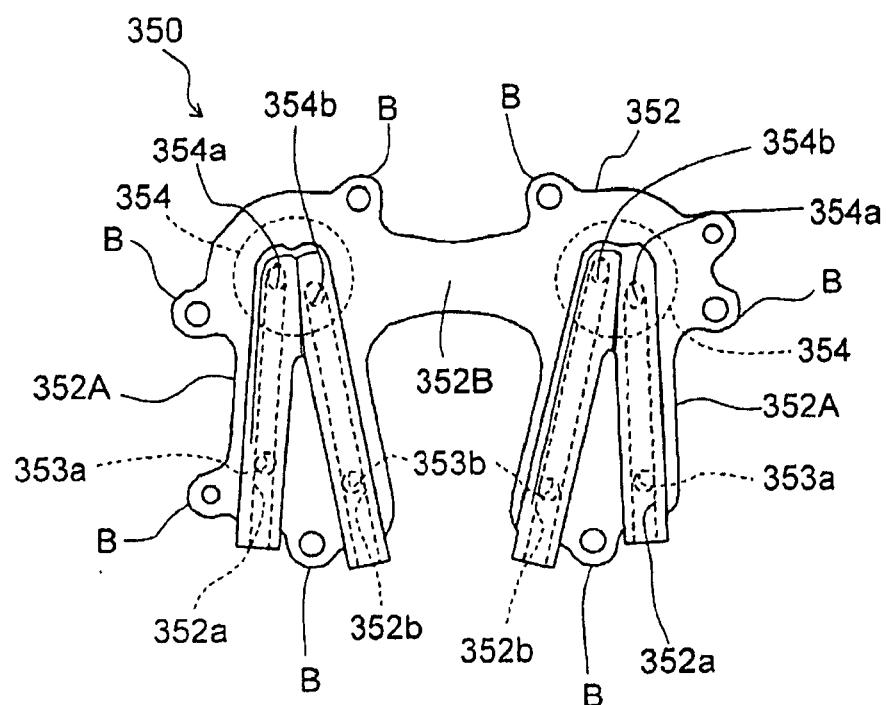


FIG. 21

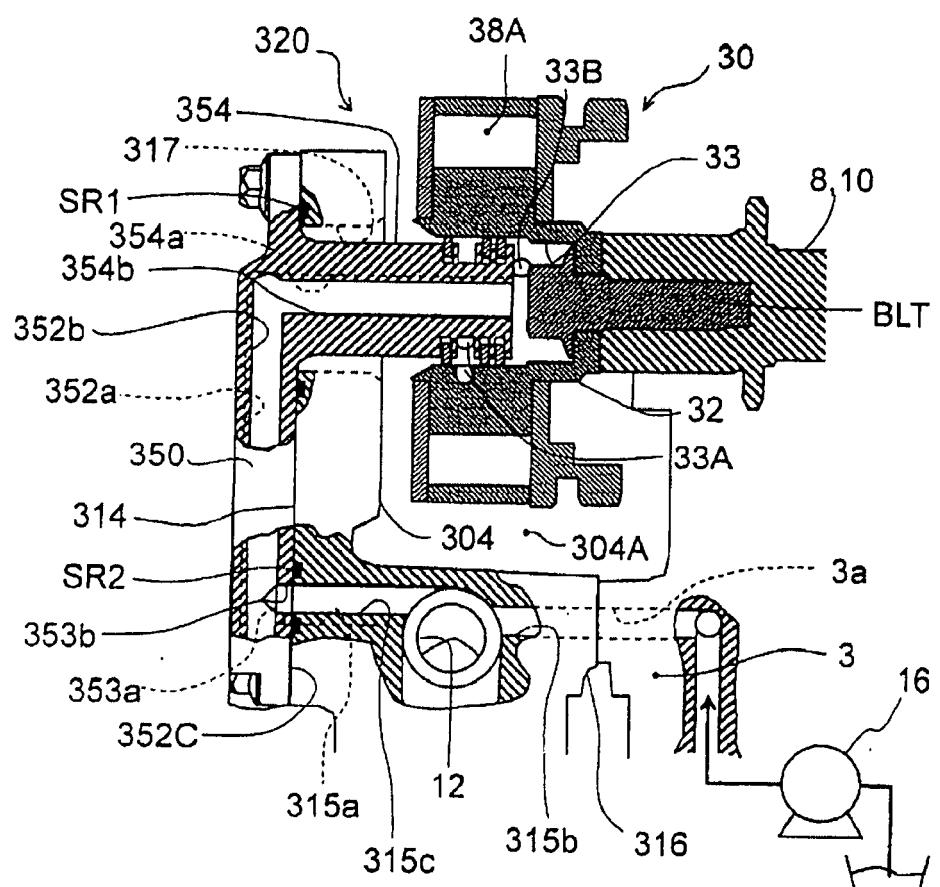


FIG. 22

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 2010028271 A [0001]
- JP 2001082115 A [0003]