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(54) Valve timimg control apparatus and internel 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).

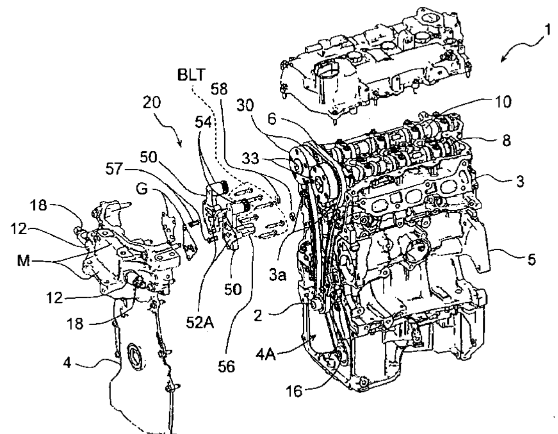

FIG. 1

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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 frontward 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

[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

[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.

[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 an 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 for 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 a 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. Figure 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 sandwitched 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 3 3 A, 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 infra-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 frontward 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 frontward 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 frontward 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 frontward 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 frontward 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. 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.

[0064] The oil passage structure of the valve timing control apparatus 320 will now be explained. Figure 22 is a cross sectional view showing an oil passage structure of the valve timing control apparatus 320. As shown in Figure 17 and Figure 22, the intermediate oil passage forming member 350 is fastened to the chain cover 304 with bolts BLT such that the mounting surface 352C of the base section 352 abuts against the frontward contact surface section 314 of the chain cover 304. Seal rings SR1 and SR1 are installed into the seal grooves 319 and 319, respectively, and seal rings SR2, SR2, SR2, and SR2 are installed into the seal ring grooves 315d, 315d, 315d, and 315d, respectively. More specifically, when the protruding shaft sections 354 and 354 of the intermediate oil passage forming member 350 are inserted into the openings 317 and 317, each of the two communication passages 353a and 353a of the intermediate oil passage forming member 350 connects to the corresponding through passage 315a on the same side of the chain cover 304, and each of the two communication passages 353b and 353b of the intermediate oil passage forming member 350 connects to the corresponding through passage 315c on the same side of chain cover 304. When the chain cover 304 is attached to the cylinder head 3 such that it covers the chain chamber 304A, the intermediate oil passage forming member 350 is arranged between the chain cover 304 and the cylinder head 3 and the protruding 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 mechanisms 30 and 30. When the chain cover 304, to which the intermediate oil passage forming member 350 has been mounted, is attached to the cylinder head, the protruding 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 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.

[0067] With the valve timing control apparatuses 20 according to the first embodiment, the intermediate oil passage forming members 50 and 50, 150 and150, 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 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 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.

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:

   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);
   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);
   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).

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).

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).

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).

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.

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.

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).

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).

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).

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.

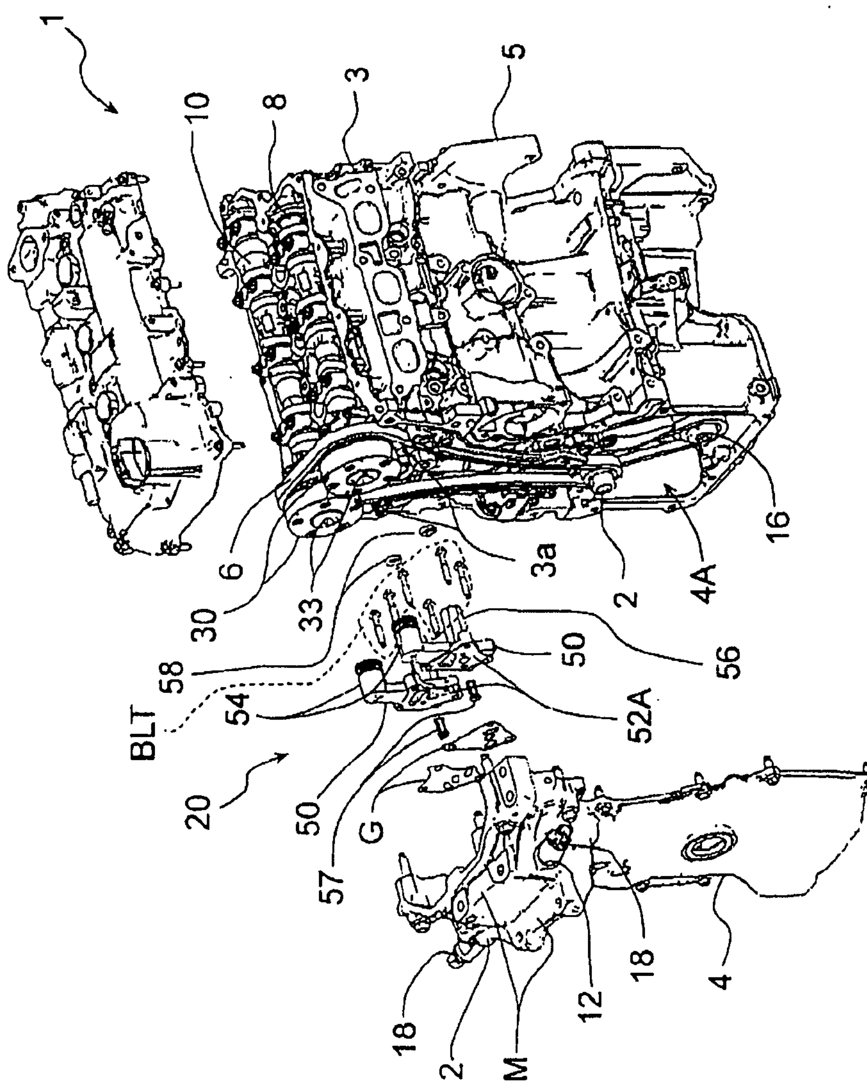
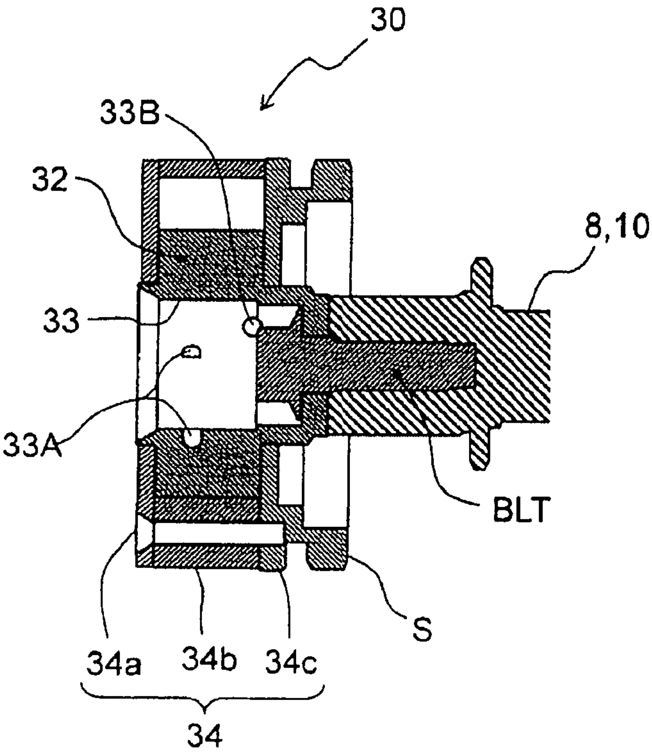
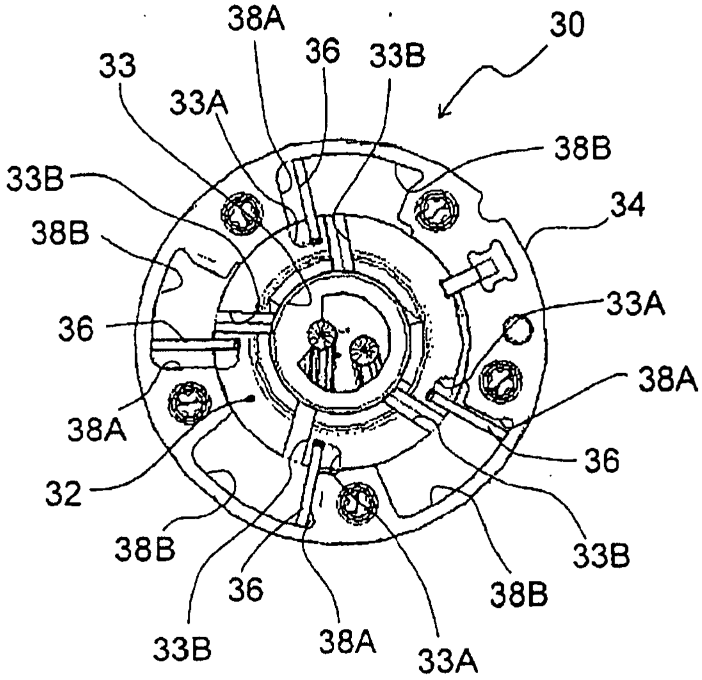


FIG. 1



F I G. 2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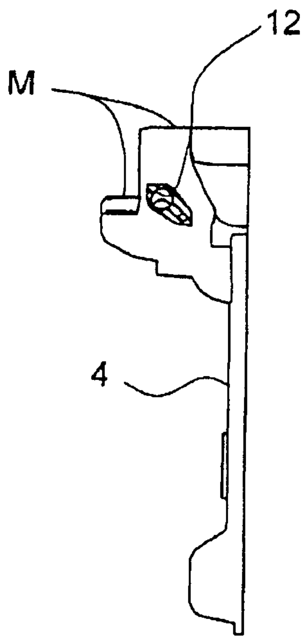
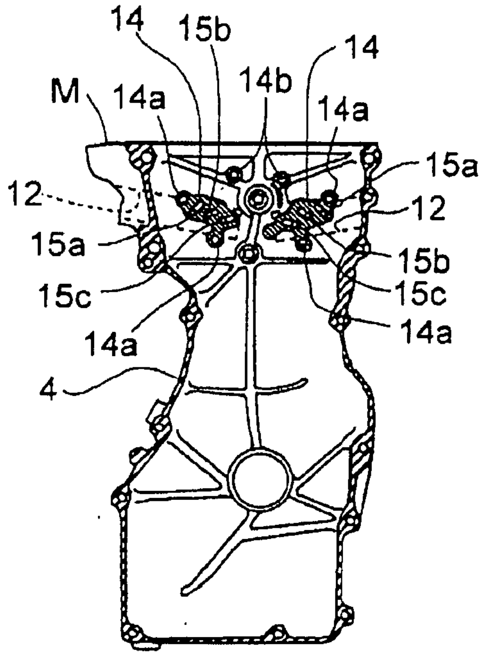
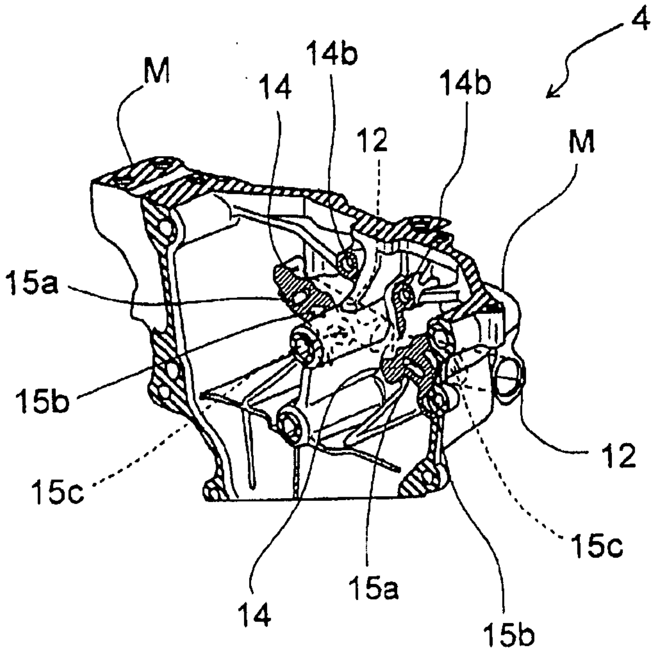
F I G. 3



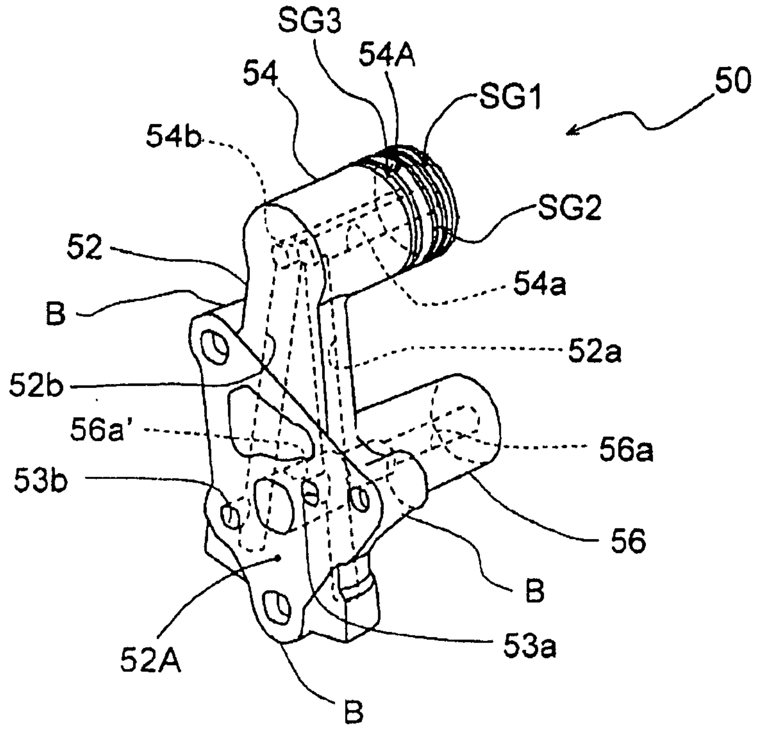
F I G. 4



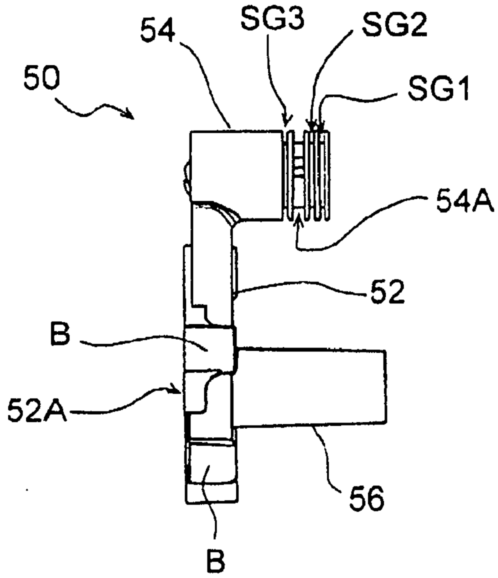
F I G. 5



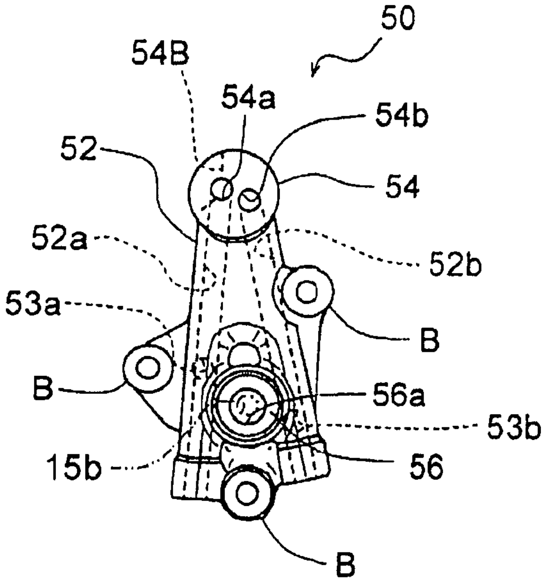
F I G. 6


SG3
54A
54
SG1
50
54b
SG2
52
54a
B
52a
52b
56a'
56a
53b
56
B
52A
53a
B

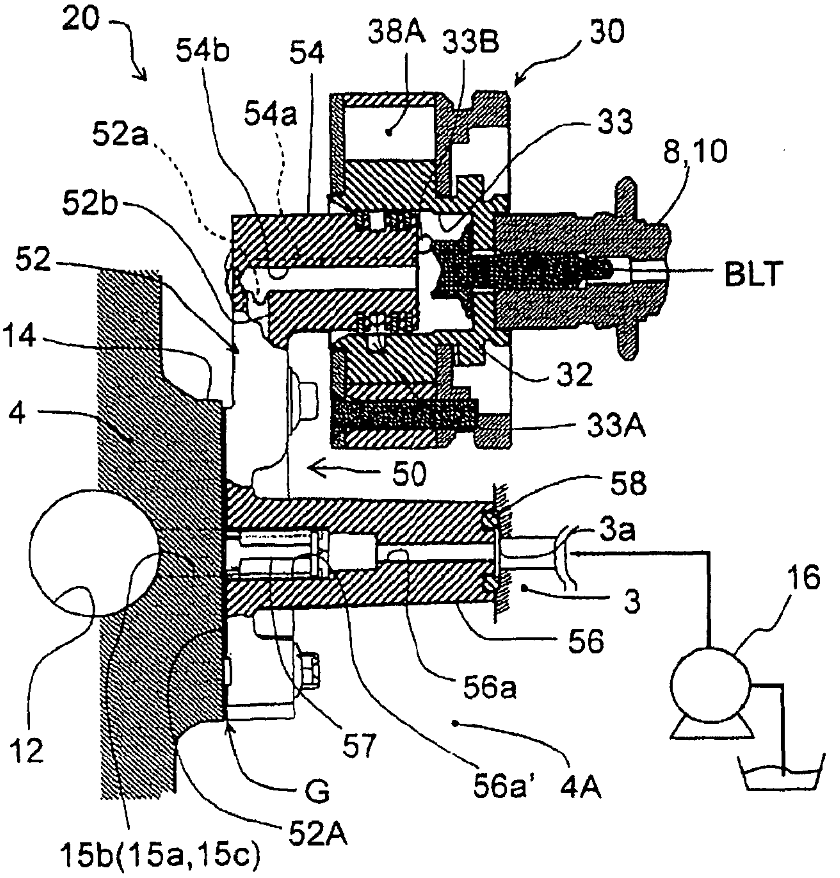
F I G. 7



F I G. 8



F I G. 9


20
54b
54
38A
33B
30
54a
33
52a
8,10
52b
BLT
52
14
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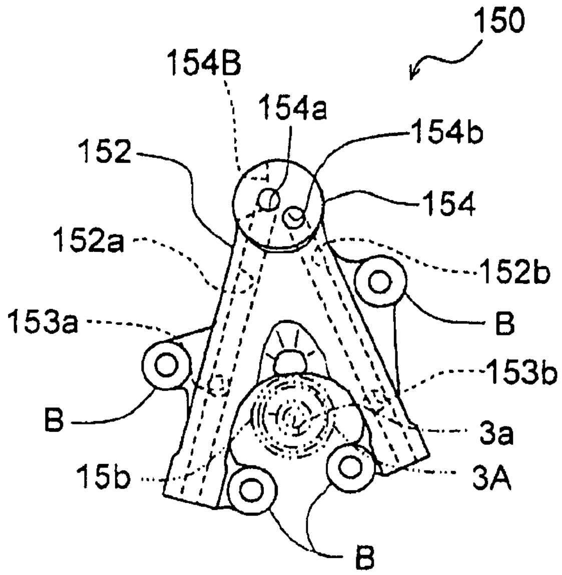
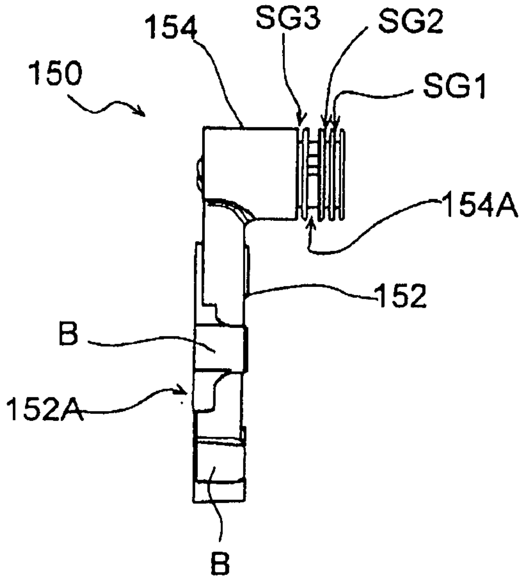
4
33A
50
58
3a
16
3
56
56a
12
57
G
56a'
4A
52A
15b(15a,15c)

F I G. 10



F I G. 11



F I G. 12

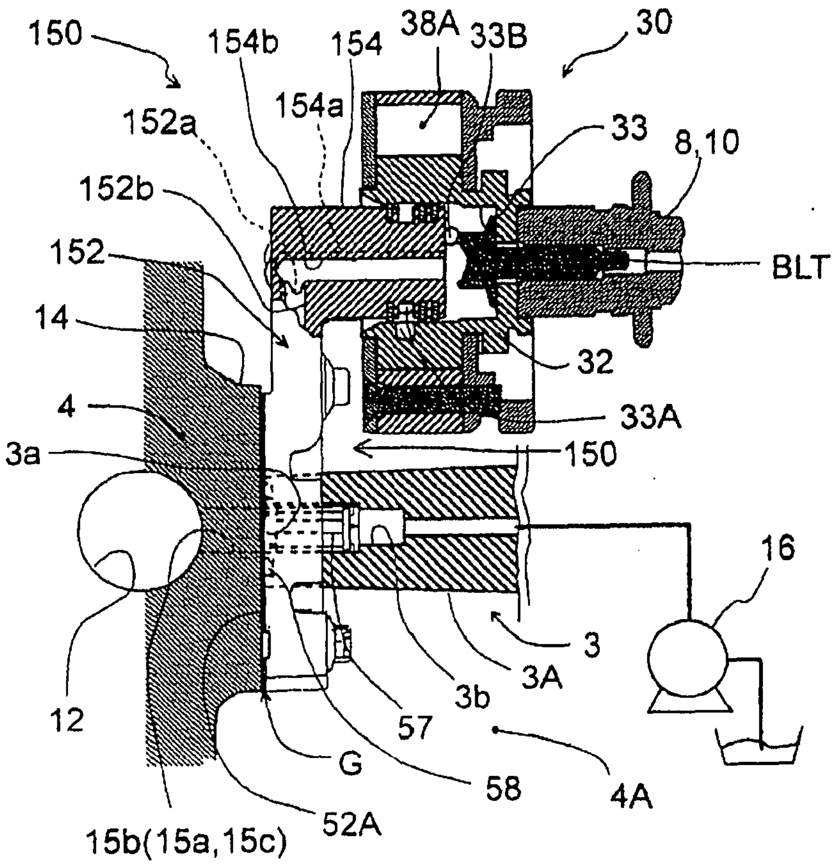
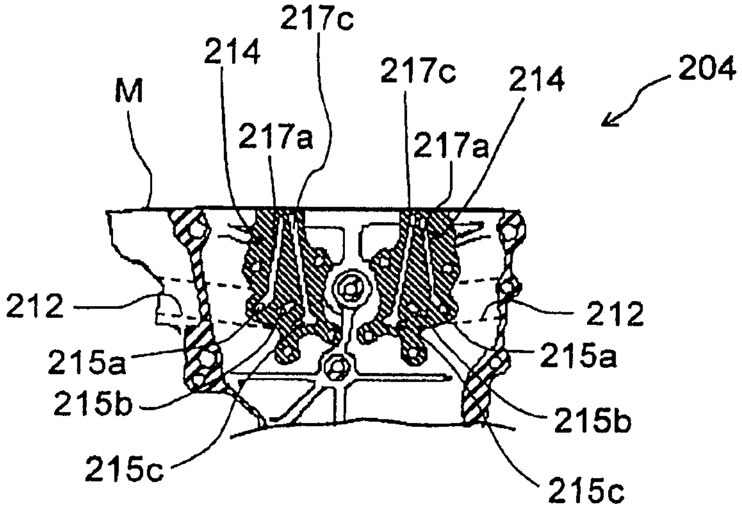
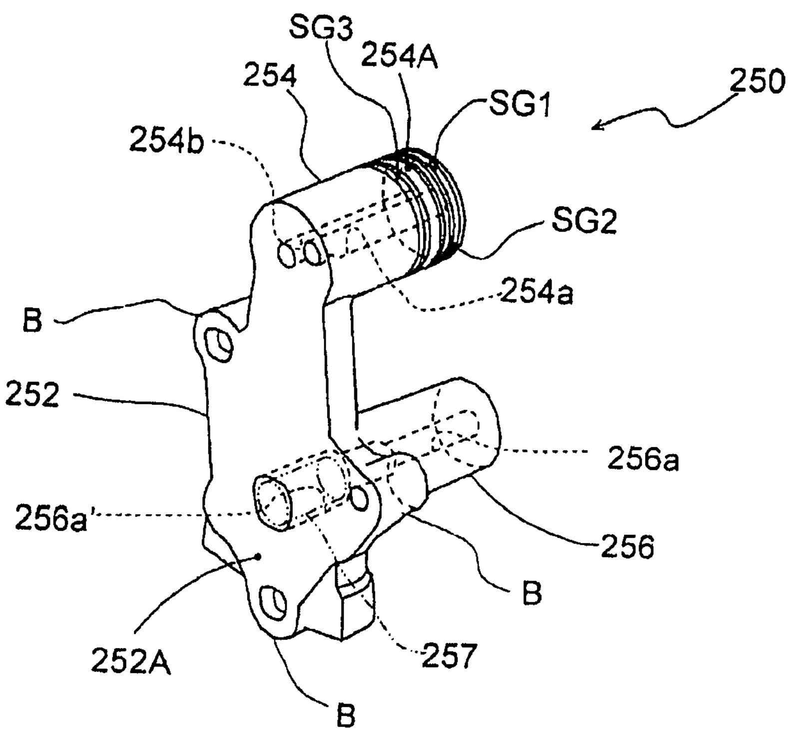

150
154b
154
38A
33B
30
152a
154a
33
8,10
152b
BLT
152
14
32
4
33A
3a
150
16
3
12
3A
3b
57
4A
G
58
52A
15b(15a,15c)

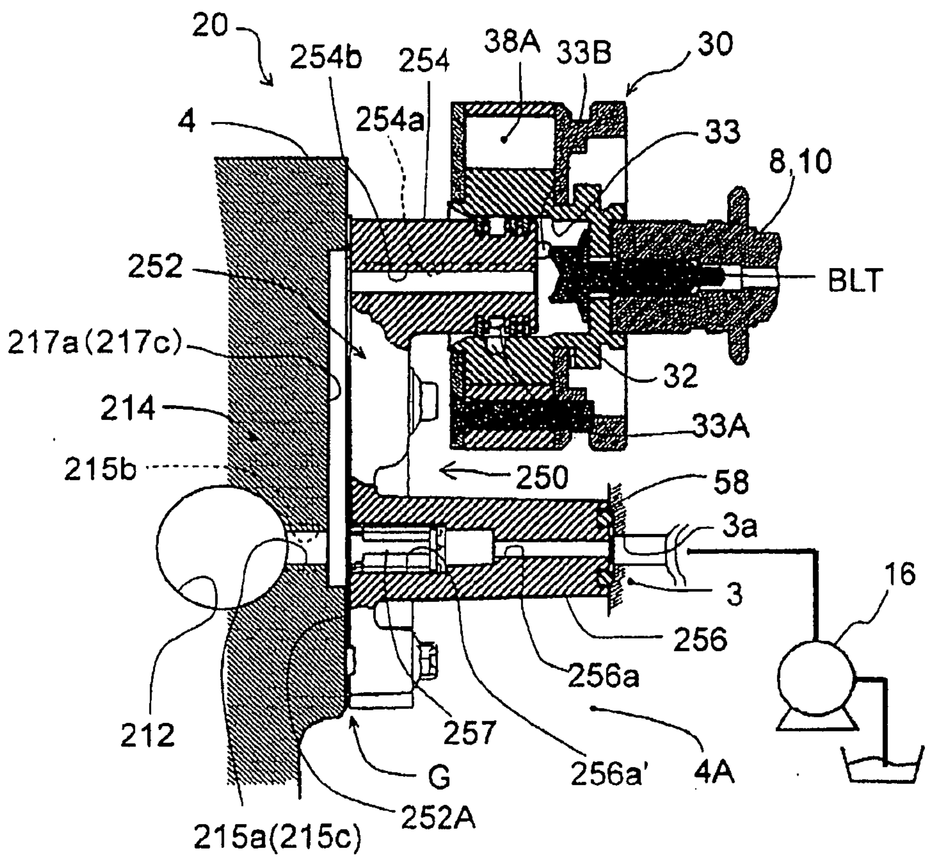
FIG. 13


217c
214
217c
214
204
M
217a
217a
212
212
215a
215a
215b
215b
215c
215c

F I G. 14


SG3
254A
254
SG1
250
254b
SG2
254a
B
252
256a
256a'
256
B
252A
257
B

F I G. 15


20
254b
254
38A
33B
30
4
254a
33
8,10
252
BLT
217a(217c)
32
214
33A
215b
250
58
3a
3
16
256
256a
212
257
4A
G
256a'
252A
215a(215c)

F I G. 16

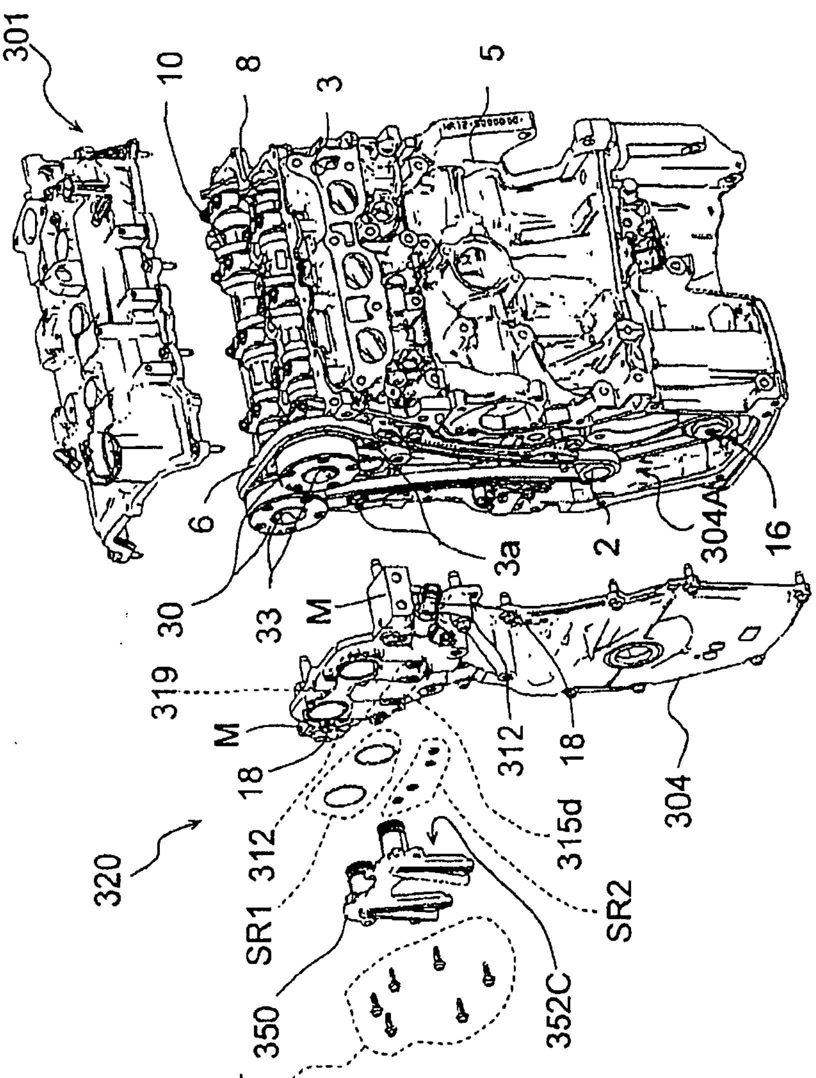
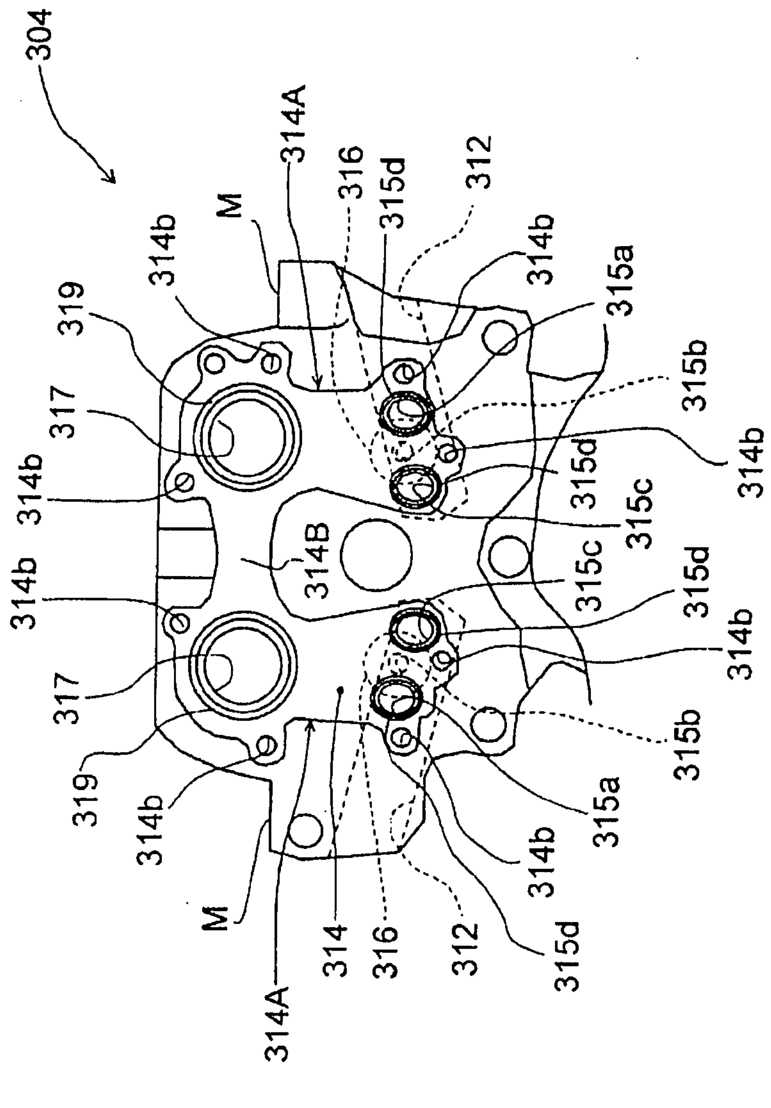
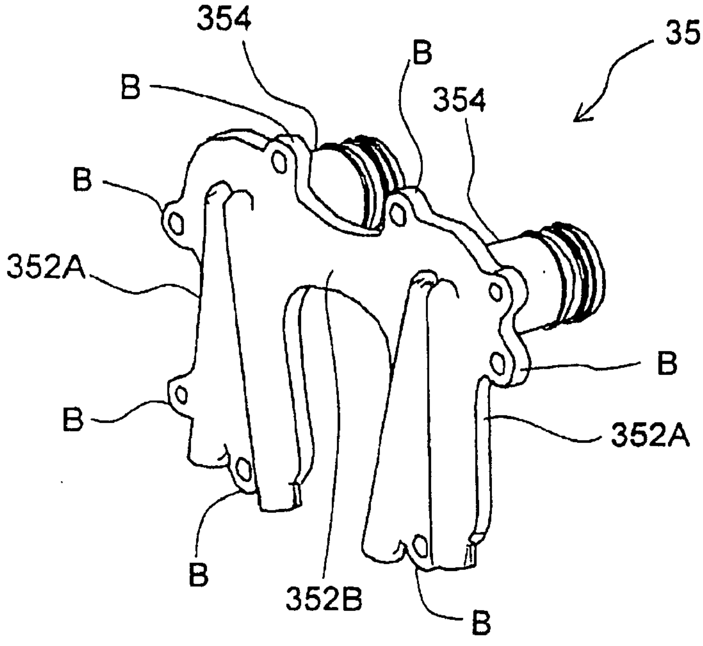

301
10
8
3
5
6
30
33
3a
2
304A
16
M
319
M
18
312
18
304
320
SR1
312
315d
SR2
350
352C
BLT

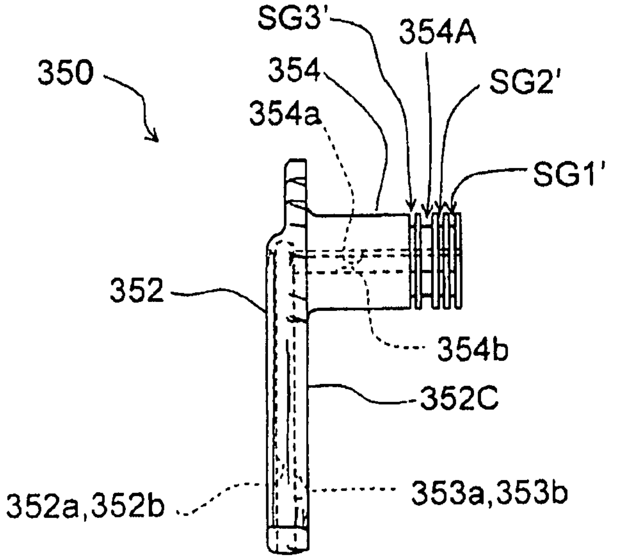
FIG. 17


304
314A
316
315d
312
M
314b
319
317
314b
314b
315a
315b
314b
315d
315c
314B
315c
315d
314b
317
319
314b
M
314A
314
316
312
315d
314b
315a
315b

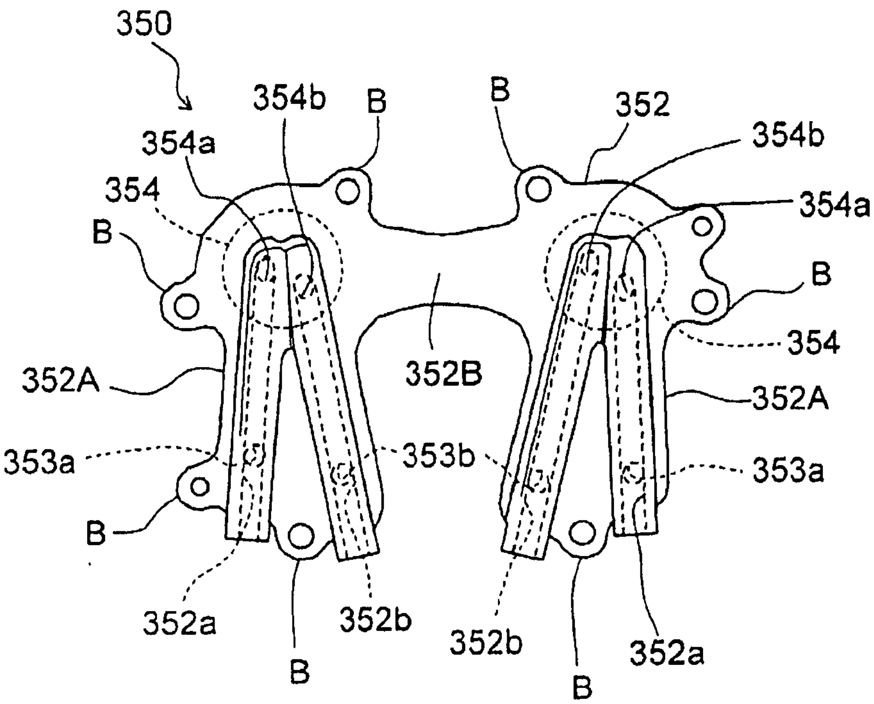
F I G. 18



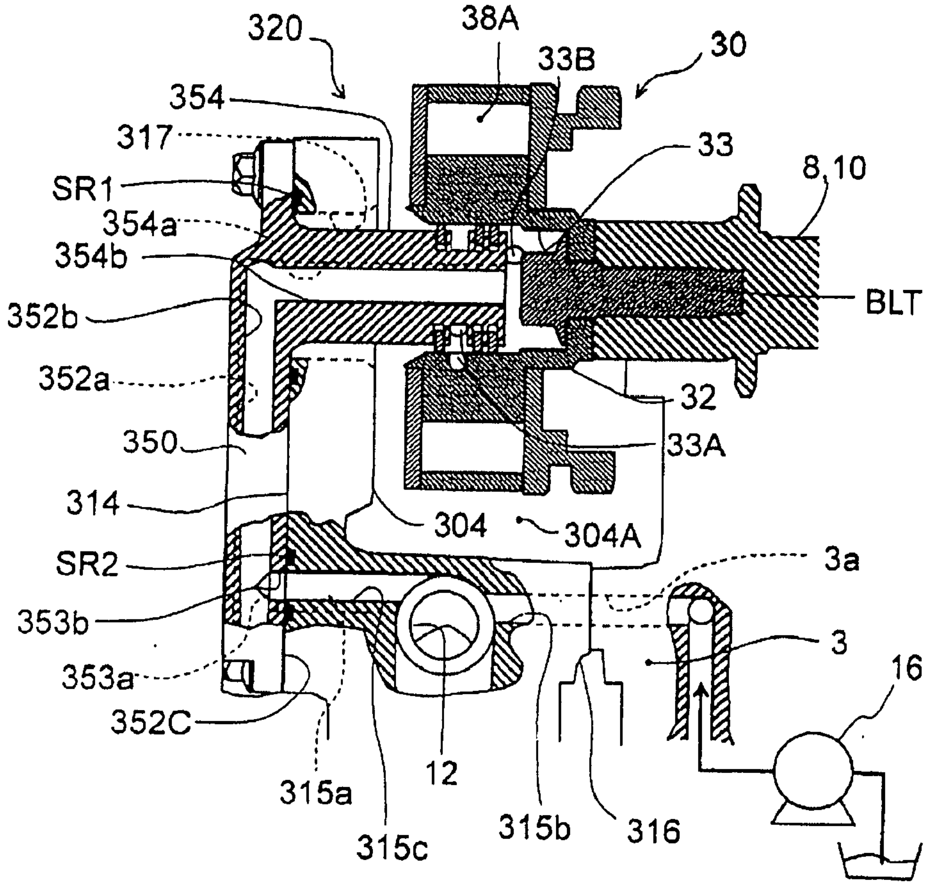
F I G. 19


350
SG3'
354A
354
SG2'
354a
SG1'
352
354b
352C
352a,352b
353a,353b

F I G. 20


350
354b
B
B
352
354b
354a
354a
354
B
B
354
352B
352A
352A
353a
353b
353b
353a
B
352a
352b
352b
352a
B
B

F I G. 21


320
38A
33B
30
354
317
33
8,10
SR1
354a
354b
BLT
352b
352a
32
350
33A
314
304
304A
SR2
3a
353b
3
16
353a
352C
12
315a
315c
315b
316

F I G. 22

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

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