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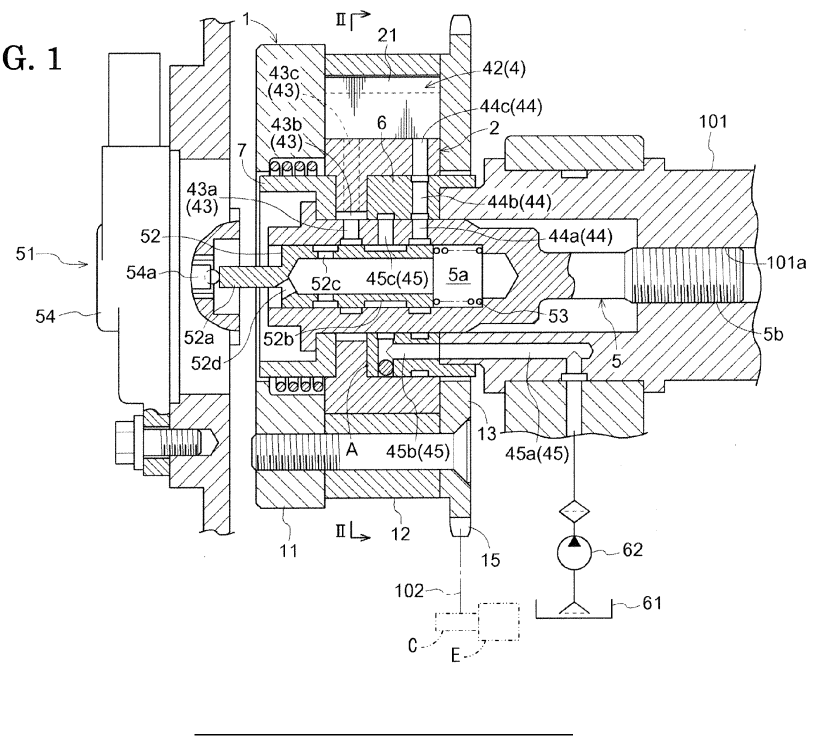
(54) Variable valve timing control apparatus

(57) A variable valve timing control apparatus, includes a housing (1) rotating in synchronization with a drive shaft (C) of an internal combustion engine (E), an inner rotor (2) arranged coaxially with the housing (1) and rotatable relative to the housing (1), a driven shaft (5, 101), an intermediate member (6) arranged between the inner rotor (2) and the driven shaft (5) and rotating in synchronization with the inner rotor (2) and the driven shaft (5), a first hydraulic fluid passage (43, 73), an inner room (43b, 73b) formed between the driven shaft (5) and the inner rotor (2) and constituting a portion of the first hydraulic fluid passage (43, 73), a second hydraulic fluid passage (44, 74), a passage (44b, 74b) formed in the intermediate member (6) and constituting a portion of the second hydraulic fluid passage (44, 74), and a contact portion (A, B) at which an axial surface of the intermediate member (6) is entirely in contact with the inner rotor (2) between the first hydraulic fluid passage (43) and the second hydraulic fluid passage (44).

F I G. 1



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Description

TECHNICAL FIELD

[0001] This disclosure generally relates to a variable valve timing control apparatus.

BACKGROUND DISCUSSION

[0002] A known variable valve timing control apparatus (cam timing device for an internal combustion engine) is disclosed in JP3965051B (hereinafter referred to as Reference 1). In the known variable valve timing control apparatus, an inner rotor (inner body in Reference 1) is fixed to a cam shaft by a shaft member such as a bolt (clamping screw in Reference 1). Two passages are formed between the inner rotor and the cam shaft so as to be positioned away from each other in an axial direction (a rotational axis) of the cam shaft.

[0003] According to the known variable valve timing control apparatus configured as described above in Reference 1, the inner rotor and the shaft member need to be made of materials having the approximately same linear expansion coefficients in order to inhibit oil supplied to the variable valve timing control apparatus form leaking therefrom to the outer side. Meanwhile, a threaded portion of the shaft member is required to have a sufficient strength. Therefore, the shaft member is generally made of a high-strength material. For example, in a case where the shaft member is being inserted into a central bore of the inner rotor so as to be screwed with the cam shaft, the inner rotor needs to be inhibited from being damaged by the high-strength material of the shaft member. As a result, the inner rotor is recommended to be made of a high-strength material having the approximately same liner expansion coefficient as that of the high-strength material of the shaft member.

[0004] However, the inner rotor does not need to be made of the high-strength material as long as the inner rotor is inhibited from being damaged by the shaft member. Utilization of the high-strength material to form the inner rotor makes further processing of the inner rotor difficult. In addition, the weight and cost of the inner rotor may increase.

[0005] A need thus exists for a variable valve timing control apparatus including an internal rotor, which does not need to be made of a high-strength material.

SUMMARY

[0006] According to an aspect of this disclosure, a variable valve timing control apparatus includes a housing rotating in synchronization with a drive shaft of an internal combustion engine and including an outer rotor, an inner rotor arranged coaxially with the housing and rotatable relative to the housing, a driven shaft to which the rotation of the inner rotor is transmitted, an intermediate member arranged between the inner rotor and the driven shaft along a rotational axis of the driven shaft and rotating in synchronization with the inner rotor and the driven shaft, a first hydraulic fluid passage, an inner room formed between the driven shaft and the inner rotor and constituting a portion of the first hydraulic fluid passage, a second hydraulic fluid passage, a passage formed in the intermediate member and constituting a portion of the second hydraulic fluid passage, and a contact portion at which an axial surface of the intermediate member is entirely in contact with the inner rotor between the first hydraulic fluid passage and the second hydraulic fluid passage along the rotational axis.

[0007] According to the aforementioned configuration of the variable valve timing control apparatus, the inner room constituting a portion of the first hydraulic fluid passages is arranged between the inner rotor and the driven shaft, therefore inhibiting the inner rotor from being in contact with the driven shaft. Accordingly, even in a case where the driven shaft is made of a high-strength material, the inner rotor does not need to be made of a high-strength material in order to inhibit the inner rotor from being damaged by a contact with the driven shaft. In addition, the variable valve timing control apparatus includes the contact portion at which the axial surface of the intermediate member is entirely in contact with the inner rotor between the first hydraulic fluid passage and the second hydraulic fluid passage along the rotational axis of the cam shaft. Accordingly, a hydraulic fluid in the first hydraulic fluid passage and the hydraulic fluid in the second hydraulic fluid passage are not mixed together with one another, thereby inhibiting deterioration of controllability of the variable valve timing control apparatus. In addition, according to the aforementioned configuration of the variable valve timing control apparatus, the driven shaft may be a bolt for fixing the inner rotor to the cam shaft. Alternatively, the driven shaft may be a different member instead of the bolt.

[0008] According to another aspect of this disclosure, the intermediate member is made of a material having a linear expansion coefficient that is close to or equal to a linear expansion coefficient of a material of the driven shaft rather than a linear expansion coefficient of a material of the inner rotor.

[0009] For example, a clearance defined between the intermediate member and the driven shaft in an assembled state is recommended to be maximally reduced while allowing the driven shaft to axially penetrate through the intermediate member, in order that the leakage of the hydraulic fluid from the clearance may be minimized. However, even in a case where the clearance is maximally reduced in the assembled state of the intermediate member and the driven shaft at a normal temperature, the variable valve timing control apparatus is actually brought in operation and thereafter reaches a high temperature. In such case, the larger a difference between the linear expansion coefficient of the intermediate member and the linear expansion coefficient of the driven shaft, the further the clearance between the intermediate member and the driven shaft may be increased. On the other hand, according to the aforementioned configuration of the variable valve timing control apparatus, the material of the intermediate member has the linear expansion coefficient that is close to or equal to the linear expansion coefficient of the material of the driven shaft rather than the linear expansion coefficient of the material of the inner rotor. Therefore, the intermediate member and the driven shaft are equally swollen even under the high-temperature environment, thereby inhibiting the clearance between the intermediate member and the driven shaft from being increased.

[0010] According to still another aspect of this disclosure, the hydraulic fluid is supplied to an outer circumferential side of the driven shaft and is supplied via the intermediate member through the second hydraulic fluid passage to the inner rotor.

[0011] Accordingly, the hydraulic fluid may be supplied via the second hydraulic fluid passage to the inner rotor without any modification or processing relative to an existing driven shaft of a known variable valve control apparatus. Consequently, even in a case where the intermediate member is additionally arranged at the known variable valve timing control apparatus, the existing driven shaft may be utilized, resulting in a cost reduction.

[0012] According to a further aspect of this disclosure, the driven shaft and the intermediate member are made of iron materials and the inner rotor is made of an aluminum material.

[0013] Accordingly, both the driven shaft and the intermediate member have high strengths and the substantially equal linear expansion coefficients from each other. Therefore, when the driven shaft is being inserted into the intermediate member, the intermediate member is inhibited from being damaged by the driven shaft. In addition, the clearance between the driven shaft and the intermediate member may be inhibited from being increased even under the high-temperature environment. Moreover, as described above, the inner rotor is made of the aluminum material; thereby, the inner rotor may be easily processed and the weight and cost of the inner rotor are effectively minimized.

[0014] According to another aspect of this disclosure, a timing sprocket is arranged at the outer rotor and a bearing portion supporting the timing sprocket is arranged at the intermediate member.

[0015] The bearing portion arranged at the intermediate member for supporting the timing sprocket requires strength. In addition, the bearing portion of the intermediate member is not made of the aluminum material forming the inner rotor but is made of the iron material. Accordingly, abrasion of the bearing portion is appropriately inhibited, therefore improving durability of the variable valve timing control apparatus.

[0016] According to still another aspect of this disclosure, the driven shaft corresponds to the cam shaft and the intermediate member is press-fitted to the cam shaft.

[0017] Accordingly, the clearance between the intermediate member and the cam shaft that serves as the driven shaft is inhibited from being increased, thereby minimizing the leakage of the hydraulic fluid from the clearance.

[0018] According to a further aspect of this disclosure, the driven shaft corresponds to a bolt screwed with the cam shaft, and a portion of a control valve switching connection and disconnection between the first hydraulic fluid passage and the second hydraulic fluid passage is accommodated within the bolt.

[0019] Accordingly, the size of the variable valve timing control apparatus may be reduced. As a result, installability of the variable valve timing control apparatus relative to the internal combustion engine may increase.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:

[0021] Fig. 1 is a cross sectional view illustrating an overall configuration of a variable valve timing control apparatus according to a first embodiment disclosed here;

[0022] Fig. 2 is a cross sectional view taken along the line II-II of Fig. 1;

[0023] Fig. 3 is a cross sectional view illustrating a detail of an oil control valve under a state where an advanced angle control of the variable valve timing control apparatus is performed;

[0024] Fig. 4 is a cross sectional view illustrating a detail of the oil control valve under a state where a retarded angle control of the variable valve timing control apparatus is performed;

[0025] Fig. 5 is an exploded perspective view illustrating a configuration of the variable valve timing control apparatus according to the first embodiment disclosed here; and

[0026] Fig. 6 is a cross sectional view illustrating an overall configuration of the variable valve timing control apparatus according to a second embodiment disclosed here.

DETAILED DESCRIPTION

[0027] First and second embodiments of a variable valve timing control apparatus of this disclosure will be explained as follows with reference to illustrations of the attached drawings. In each of the first and second embodiments, the variable valve timing control apparatus is arranged at a suction valve in an engine E for a vehicle. The engine E for the vehicle in each of the first and second embodiments corresponds to an internal combustion engine.

[0028] [Overall configuration] As illustrated in Fig. 1, the variable valve timing control apparatus according to the first embodiment includes a housing 1 rotating in synchronization with a crank shaft C serving as a drive shaft of the engine E, and an inner rotor 2 arranged coaxially with the housing 1 and rotatable relative thereto. An intermediate member 6 is arranged between the inner rotor 2 and a bolt 5 serving as a driven shaft to which a rotation of the inner rotor 2 is transmitted (the bolt 5 will be hereinafter referred to as an OCV bolt 5). Then, the rotation of the inner rotor 2 transmitted from the driven shaft is transmitted to a rotary shaft of a cam. A cam shaft 101 corresponds to the rotary shaft of the cam controlling opening and closing operations of the suction valve of the engine E. The cam shaft 101 rotates in synchronization with the inner rotor 2, the OCV bolt 5, and the intermediate member 6. Further, the cam shaft 101 is rotatably attached to a cylinder head of the engine E.

[0029] [Housing and inner rotor] As shown in Fig. 1, the housing 1 integrally includes a front plate 11, an outer rotor 12 arranged around a circumferential outer side of the inner rotor 2, and a rear plate 13 integrated with a timing sprocket 15. The front plate 11 is arranged at a first side of the housing 1 in an opposite direction from a second side of the housing 1 along a rotational axis of the cam shaft 101 connected to the second side of the housing 1. The inner rotor 2 is accommodated in the housing 1; thereby, fluid pressure chambers 4 are formed between the inner rotor 2 and the outer rotor 12 as will be described below.

[0030] The crank shaft C is rotationally driven and a driving force of the crank shaft C is transmitted via a driving force transmission member 102 to the timing sprocket 15. Then, the housing 1 rotates in a rotating direction indicated by an arrow S in Fig. 2, thereby rotating the cam shaft 101 and allowing the cam arranged at the cam shaft 101 to move the suction valve downwardly to open the suction valve.

[0031] As illustrated in Fig. 2, the outer rotor 12 includes plural protruding portions 14 protruding radially inwardly and positioned at intervals from one another along the rotating direction S; thereby, the fluid pressure chambers 4 are formed between the inner rotor 2 and the outer rotor 12. Each of the protruding portions 14 serves as a shoe slidably contacting an outer circumferential surface of the inner rotor 2. The inner rotor 2 includes protruding portions 21 protruding radially outwardly. Each of the protruding portions 21 is arranged at a portion of the outer circumferential surface, which faces each of the fluid pressure chambers 4. The fluid pressure chamber 4 is partitioned by the protruding portion 21 into an advanced angle chamber 41 and a retarded angle chamber 42 along the rotating direction S. In addition, the four fluid pressure chambers 4 are provided in the first embodiment; however, less than or more than the four fluid pressure chambers 4 may be formed in the variable valve timing control apparatus of the first embodiment.

[0032] Oil (hydraulic fluid) is supplied to and discharged from the advanced angle chambers 41 and the retarded angle chambers 42, or the supply/discharge of the oil to/from the advanced angle chambers 41 and the retarded angle chambers 42 is stopped. Therefore, a hydraulic pressure of the oil is applied to the protruding portions 21. Thus, a relative rotational phase between the housing 1 and the inner rotor 2 is shifted in an advanced angle direction or a retarded angle direction, or is maintained in any desired phase. The advanced angle direction indicated by an arrow S1 in Fig. 2 is a direction in which a capacity of the advanced angle chamber 41 increases. Meanwhile, the retarded angle direction indicated by an arrow S2 in Fig. 2 is a direction in which a capacity of the retarded angle chamber 42 increases. In addition, a most advanced angle phase is obtained when the capacity of the advanced angle chamber 41 is largest. Meanwhile, a most retarded angle phase is obtained when the capacity of the retarded angle chamber 42 is largest.

[0033] [Lock mechanism] The variable valve timing control apparatus includes a lock mechanism 8 that may lock the relative rotational phase of the inner rotor 2 to the housing 1 at a predetermined phase between the most advanced angle phase and the most retarded angle phase (the predetermined phase will be hereinafter referred to as a lock phase). In a state where the hydraulic pressure of the oil is not stable right after the engine E starts, the lock mechanism 8 locks the relative rotational phase at the lock phase, thereby appropriately maintaining a rotational phase of the cam shaft 101 relative to a rotational phase of the crank shaft C. As a result, a stable rotating speed of the engine E may be obtained.

[0034] As illustrated in Fig. 2, the lock mechanism 8 includes a lock member 81 movable along the rotational axis of the cam shaft 101 and a lock passage 82 formed in the inner rotor 2. The lock member 8 is biased by a biasing member and is maintained in an engaged state with a lock groove formed at the front plate 11 or the rear plate 13, thereby being maintained in a locked state. The lock passage 82 connects to advanced angle passages 43. In a case where an advanced angle control of the variable valve timing control apparatus is performed, the oil is supplied to the lock passage 82 to thereby apply the hydraulic pressure to the lock mechanism 8. As a result, the lock member 81 is released from the lock groove against a biasing force of the biasing member, therefore being released from the locked state.

[0035] [OCV (oil control valve)] As illustrated in Fig. 1, an oil control valve (OCV) 51 serving as a control valve is arranged coaxially with the cam shaft 101. The OCV 51 includes a spool 52, a spring 53 biasing the spool 52, and an electromagnetic solenoid 54 driving the spool 52. The electromagnetic solenoid 54 is a known electromagnetic solenoid; therefore, a detailed explanation of the electromagnetic solenoid 54 will be omitted herein.

[0036] The spool 52 is accommodated in an accommodating portion 5a formed in a first end portion of the OCV bolt 5, which is located at the housing 1. The spool 52 is slidably movable within the accommodating portion 5a along the rotational axis of the cam shaft 101. An external threaded portion 5b is formed at a second end portion of the OCV bolt 5 (the second end portion is axially opposite from the first end portion). The external threaded portion 5b of the OCV bolt 5 is screwed with an internal threaded portion 101 a of the cam shaft 101, thereby fixing the OCV bolt 5 to the cam shaft 101.

[0037] The spring 53 is arranged in the accommodating portion 5a so as to be in the vicinity of the cam shaft 101, thereby consistently biasing the spool 52 toward an opposite side of the cam shaft 101 along the rotational axis. The electromagnetic solenoid 54 is powered and a push pin 54a arranged at the electromagnetic solenoid 54 axially presses against a rod portion 52a formed at the spool 52. As a result, the spool 52 axially slides toward the cam shaft 101 against a biasing force of the spring 53. A duty ratio of electric power supplied to the electromagnetic solenoid 54 is adjusted, thereby axially adjusting a position of the spool 52 of the OCV 51. A feed amount of the electric power supplied to the electromagnetic solenoid 54 is controlled by an electric control unit (ECU).

[0038] [Intermediate member and washer member] As illustrated in Fig. 5, the intermediate member 6 formed in a hollow cylindrical shape is arranged in the inner rotor 2 so as to be axially positioned close to the cam shaft 101 (to the right side seen in Fig. 5). In addition, a bearing portion for the timing sprocket 15 is arranged at the intermediate member 6. A washer 7 is arranged in the inner rotor 2 so as to be axially positioned at the opposite side of the cam shaft 101 (to the left side seen in Fig. 5). The OCV bolt 5 is inserted through central bores of the housing 1, the washer 7, the inner rotor 2, and the intermediate member 6 under a state where the intermediate member 6 and the washer 7 are arranged in the inner rotor 2 and the housing 1 is arranged around the circumferential outer side of the inner rotor 2. As s result, as illustrated in Fig. 1, an axial surface of the intermediate member 6, which axially faces the front plate 11, and an axial surface of the washer 7, which axially faces the rear plate 13, are entirely in contact with the inner rotor 2 along the rotational axis of the cam shaft 101; therefore, a contact portion A between the inner rotor 2 and the intermediate member 6 is formed.

[0039] In addition, the washer 7 functions to increase a connecting force of the OCV bolt 5 relative to the cam shaft 101; however, the washer 7 is not an essential component for the variable valve timing control apparatus according to the first embodiment. Alternatively, a component having the same function as the washer 7 and formed into a different shape from the shape of the washer 7 may be utilized in the variable valve timing control apparatus of the first embodiment. In addition, the component may be arranged at a different position from the position of the washer 7 in the first embodiment.

[0040] [Configuration of oil passage] As illustrated in Fig. 1, the oil is stored in an oil pan 61. The driving force of the crank shaft C is transmitted to a mechanical oil pump 62; thereby, the oil in the oil pan 61 is pumped by the oil pump 62 and is supplied to a supply passage 45 that will be described below. Then, the OCV 51 controls the supply/discharge of the oil from/ to advanced angle passages 43 and retarded angle passages 44 and controls to stop the supply/discharge of the oil from/ to the advanced angle passage 43 and the retarded angle passages 44. In other words, a portion (the spool 52) of the OCV 51 switches connection and disconnection between the advanced angle passages 43 and the retarded angle passages 44.

[0041] As illustrated in Figs. 1 and 2, the advanced angle passages 43 connecting to the advanced angle chambers 41, respectively and serving as first hydraulic fluid passages are formed by through-holes 43a formed in the OCV bolt 5, an inner room 43b formed between the OCV bolt 5 and the inner rotor 2, and through-holes 43c formed in the inner rotor 2. Meanwhile, the retarded angle passages 44 connecting to the retarded angle chambers 42, respectively and serving as second hydraulic fluid passages are formed by through-holes 44a formed in the OCV bolt 5, through-holes 44b formed in the intermediate member 6 and serving as passages constituting portions of the second hydraulic fluid passages, and through-holes 44c formed in the inner rotor 2. Further, the supply passage 45 supplying the oil to the advanced angle chambers 41 or the retarded angle chambers 42 is formed by a passage 45a formed in the cam shaft 101, a passage 45b formed in the intermediate member 6, and through-holes 45c formed in the OCV bolt 5.

[0042] The oil flowing through the supply passage 45 firstly flows into an annular groove 52b formed at an outer circumferential surface of the spool 52. As illustrated in Fig. 1, in a state where the annular groove 52b is not in connection with the through-holes 43a and 44a formed in the OCV bolt 5, the oil is not supplied to the advanced angle chambers 41 and the retarded angle chambers 42. Under such condition, the through-holes 43a are not in connection with through-holes 52c formed in the spool; therefore, the oil in the advanced angle chambers 41 is not discharged therefrom through the through-holes 52c, the accommodating portion 5a, and a discharge hole 52d to an outer side of the variable valve timing control apparatus. Likewise, under the condition where the annular groove 52b is not in connection with the through-holes 43a and 44a, the through-holes 44a are not in connection with the accommodating portion 5a. Accordingly, the oil in the retarded angle chambers 42 is not discharged therefrom through the retarded angle passages 44, the accommodating portion 5a, and the discharge hole 52d to the outer side of the variable valve timing control apparatus. That is, a predetermined feed amount of the electric power is supplied to the electromagnetic solenoid 54 so that the OCV 51 controls the spool 52 to be maintained in a position shown in Fig. 1. As a result, the supply/ discharge of the oil to/from the advanced angle chambers 41 and the retarded angel chambers 42 is stopped and the relative rotational phase between the housing 1 and the inner rotor 2 is maintained.

[0043] In a case where the electromagnetic solenoid 54 is not powered, the spool 52 is maintained in a position shown in Fig. 3, by means of the biasing force of the spring 53. In such condition in Fig. 3, the annular groove 52b of the spool 52 is in connection with the through-holes 43a of the OCV bolt 5 and is not in connection with the through-holes 44a of the OCV bolt 5. In addition, the through-holes 44a are simultaneously in connection with the accommodating portion 5a. Accordingly, the oil supplied to the supply passage 45 is supplied through the advanced angle passages 43 to the advanced angle chambers 41. Meanwhile, the oil in the retarded angle chambers 42 is discharged therefrom through the retarded angle passages 44, the accommodating portion 5a, and the discharge hole 52d to the outer side of the variable valve timing control apparatus. At this time, the relative rotational phase between the housing 1 and the inner rotor 2 is shifted in the advanced angle direction S1 by the hydraulic pressure applied to the advanced angle chambers 41.

[0044] In a case where the electromagnetic solenoid 54 is maximally powered, the spool 52 is maintained in a position shown in Fig. 4 against the biasing force of the spring 53. In such condition in Fig. 4, the annular groove 52b of the spool 52 is in connection with the through-holes 44a of the OCV bolt 5 and is not in connection with the through-holes 43a of the OCV bolt 5. In addition, the through-holes 43a are simultaneously in connection with the through-holes 52c of the spool 52. Accordingly, the oil supplied to the supply passage 45 is supplied through the retarded angle passages 44 to the retarded angle chambers 42. In particular, the oil is supplied from the supply passage 45 to an outer circumferential side of the OCV bolt 5 and is thereafter supplied via the intermediate member 6 through the retarded angle passages 44 to the inner rotor 2. Meanwhile, the oil in the advanced angle chambers 41 is discharged therefrom through the advanced angle passages 43, the through-holes 52c, the accommodating portion 5a, and the discharge hole 52d to the outer side of the variable valve timing control apparatus. At this time, the relative rotational phase between the housing 1 and the inner rotor 2 is shifted in the retarded angle direction S2 by the hydraulic pressure applied to the retarded angle chambers 42.

[0045] [Effects] In the variable valve timing control apparatus configured as described above in the first embodiment, the intermediate member 6 and the inner room 43b are axially arranged between the OCV bolt 5 and the inner rotor 2. Accordingly, the OCV bolt 5 is not in contact with the inner rotor 2. Consequently, even in a case where the OCV bolt 5 is made of a high-strength material, the inner rotor 2 does not need to be made of a high-strength material in order to inhibit the inner rotor 2 from being damaged by a contact with the OCV volt 5. For example, in a case where the inner rotor 2 is made of an aluminum material, the inner rotor 2 may be easily processed. In addition, the weight and cost of the inner rotor 2 are effectively minimized.

[0046] In addition, the variable valve timing control apparatus according to the first embodiment includes the contact portion A at which the axial surface of the intermediate member 6, axially facing the front plate 11 is entirely in contact with the inner rotor 2 between the advanced angle passages 43 and the retarded angle passages 44 along the rotational axis of the cam shaft 101. Accordingly, the oil in the advanced angle passages 43 and the oil in the retarded angle passages 44 are not mixed together with one another in a clearance between the inner rotor 2 and the intermediate member 6. Consequently, controllability of the variable valve timing control apparatus may not deteriorate.

[0047] Moreover, for example, the intermediate member 6 is made of a material having a linear expansion coefficient that is substantially equal to or close to a linear expansion coefficient of the material of the OCV bolt 5. In such case, the OCV bolt 5 and the intermediate member 6 are substantially equally swollen under a high-temperature environment, thereby inhibiting the clearance between the OCV bolt 5 and the intermediate member 6 from being increased. As a result, leakage of the oil from the clearance is inhibited and the controllability of the variable valve timing control apparatus may be maintained. For example, in a case where the OCV bolt 5 and the intermediate member 6 are made of iron materials, strength requirements for the OCV bolt 5 and the intermediate member 6 are satisfied. Furthermore, the OCV bolt 5 and the intermediate member 6 appropriately have the substantially same linear expansion coefficients. In addition, the housing 1, the washer 7, the inner rotor 2, the intermediate member 6, and the like are axially fixed to one another by the OCV bolt 5. Accordingly, even in a case where the housing 1, the washer 7, the inner rotor 2, the intermediate member 6, and the like are swollen under the high-temperature environment, a clearance may not be easily generated at the contact portion A between the inner rotor 2 and the intermediate member 6.

[0048] The variable valve timing control apparatus according to the second embodiment will be explained as follows with reference to Fig. 6. A basic configuration of the variable valve timing control apparatus according to the second embodiment is the same as that of the variable valve timing control apparatus according to the first embodiment. Therefore, differences in the variable valve timing control apparatus between the first and second embodiments will be described below. In addition, the same reference numbers are assigned to the same components in the first and second embodiments.

[0049] According to the variable valve timing control apparatus of the second embodiment, the cam shaft 101 penetrates through the central bore of the inner rotor 2 along the rotational axis. The cam shaft 101 serves as the driven shaft. An inner room 101 b into which a bolt 91 is inserted is formed in an end portion of the cam shaft 101. An external threaded portion 91 a formed at the bolt 91 is screwed with the internal threaded portion 101 a of the cam shaft 101; thereby, the inner rotor 2 arranged in the housing 1 is fixed to the cam shaft 101.

[0050] The OCV 51 is arranged at the variable valve timing control apparatus in the first embodiment. On the other hand, the OCV 51 is arranged at the oil pump 62 in the second embodiment. In other words, the OCV 51 controls the oil to be supplied to any of the advanced angle chambers 41 and the retarded angle chambers 42 that will be described below; thereafter, the oil flows into the variable valve timing control apparatus. The supply passage 45 described in the first embodiment is not provided at the variable valve timing control apparatus according to the second embodiment.

[0051] The advanced angle passages 73 connecting to the advanced angle chambers 41, respectively and serving as the first hydraulic fluid passages are formed by a passage 73a formed in the cam shaft 101, an inner room 73b formed between the cam shaft 101 and the inner rotor 2, and through-holes 73c formed in the inner rotor 2. Meanwhile, the retarded angle passages 74 connecting to the retarded angle chambers 42, respectively and serving as the second hydraulic fluid passages are formed by passages 74a formed in the cam shaft 101, passages 74b formed in the intermediate member 6, and through-holes 74c formed in the inner rotor 2. The passages 74b serve as passages constituting portions of the retarded angle passages 74.

[0052] In the variable valve timing control apparatus configured as described above in the second embodiment, the intermediate member 6 and the inner room 73b constituting a portion of the advanced angle passages 73 are arranged between the cam shaft 101 and the inner rotor 2. Accordingly, the cam shaft 101 is not in contact with the inner rotor 2. Consequently, even in a case where the cam shaft 101 is made of a high-strength material, the inner rotor 2 does not need to be made of a high-strength material in order to inhibit the inner rotor 2 from being damaged by a contact with the cam shaft 101. Moreover, the intermediate member 6 includes the axial surface axially facing the front plate 11 and defined at the contact portion A relative to the inner rotor 2. Therefore, the oil in the advanced angle passages 73 is not mixed together with the oil in the retarded angle passages 74, thereby inhibiting the deterioration of the controllability of the variable valve timing control apparatus.

[0053] As described above, the intermediate member 6 includes the axial surface axially facing the front plate 11 and defined at the contact portion A relative to the inner rotor 2, and an axial surface axially facing the rear plate 13 and defined at a contact portion B relative to the inner rotor 2. The contact portion B is arranged between the advanced angle passages 73 and the retarded angle passages 74. The intermediate member 6 is configured so that not only the axial surface defined at the contact portion A but also the axial surface defined at the contact portion B may be entirely in contact with the inner rotor 2 along the rotational axis of the cam shaft 101. As illustrated in Fig. 6, the passages 74b formed in the intermediate member 6 are configured so as to be axially in connection with the passages 74a formed in the cam shaft 101. As a result, even in a case where a clearance is generated between the intermediate member 6 and the cam shaft 101, the oil in the advanced angle passages 73 is not mixed together with the oil in the retarded angle passages 74, therefore inhibiting the deterioration of the controllability of the variable vale timing control apparatus. In the case that the passages 74b are axially in connection with the passages 74a, the intermediate member 6 does not need to be made of the material having the linear expansion coefficient that is substantially equal to or close to a linear expansion coefficient of the material of the cam shaft 101, therefore offering a wide selection of materials for forming the intermediate member 6.

[0054] Furthermore, according to the second embodiment, the intermediate member 6 and the cam shaft 101 are press-fitted to each other; thereafter, the inner rotor 2 may be attached to a circumferential outer side of the intermediate member 6. Accordingly, a clearance is inhibited from being axially generated between the intermediate member 6 and the cam shaft 101. For example, in a case where a variable valve timing control apparatus includes an oil passage configuration where a clearance is axially generated between the intermediate member 6 and the cam shaft 101, the oil in the advanced angle passages 73 may be mixed together with the oil in the retarded angle passages 74. In such case, press-fitting the intermediate member 6 to the cam shaft 101 as described in the first embodiment inhibits the clearance from being axially generated between the intermediate member 6 and the cam shaft, therefore not deteriorating the controllability of the variable valve timing control apparatus.

[0055] (1) The variable valve timing control apparatus according to each of the first and second embodiments may be adapted to be arranged at an exhaust valve in the engine E. (2) The variable valve timing control apparatus according to each of the first and second embodiments may not include the lock mechanism 8. (3) The oil passage configuration in each of the first and second embodiments may be modified as long as the modified oil passage configuration does not affect the operational function of the variable valve timing control apparatus. (4) According to the first and second embodiments, each of the OCV bolt 5 and the cam shaft 101 serves as the driven shaft. Alternatively, a different member may be adapted as the driven shaft instead of the OCV bolt 5 or the cam shaft 101. (5) The arrangement and shape of the intermediate member 6 described in each of the first and second embodiments may be modified.

[0056] The variable valve timing control apparatus according to each of the first and second embodiments of the disclosure may be utilized in the internal combustion engine E for the vehicle and the like.

Claims

1. A variable valve timing control apparatus, comprising:

   a housing (1) rotating in synchronization with a drive shaft (C) of an internal combustion engine (E) and including an outer rotor (12);
   an inner rotor (2) arranged coaxially with the housing (1) and rotatable relative to the housing (1);
   a driven shaft (5, 101) to which the rotation of the inner rotor (2) is transmitted;
   an intermediate member (6) arranged between the inner rotor (2) and the driven shaft (5) along a rotational axis of the driven shaft (5, 101) and rotating in synchronization with the inner rotor (2) and the driven shaft (5);
   a first hydraulic fluid passage (43, 73);
   an inner room (43b, 73b) formed between the driven shaft (5) and the inner rotor (2) and constituting a portion of the first hydraulic fluid passage (43, 73);
   a second hydraulic fluid passage (44, 74);
   a passage (44b, 74b) formed in the intermediate member (6) and constituting a portion of the second hydraulic fluid passage (44, 74); and
   a contact portion (A, B) at which an axial surface of the intermediate member (6) is entirely in contact with the inner rotor (2) between the first hydraulic fluid passage (43, 73) and the second hydraulic fluid passage (44, 74) along the rotational axis.

2. The variable valve timing control apparatus according to Claim 1, wherein the intermediate member (6) is made of a material having a linear expansion coefficient that is close to or equal to a linear expansion coefficient of a material of the driven shaft (5) rather than a linear expansion coefficient of a material of the inner rotor (2).

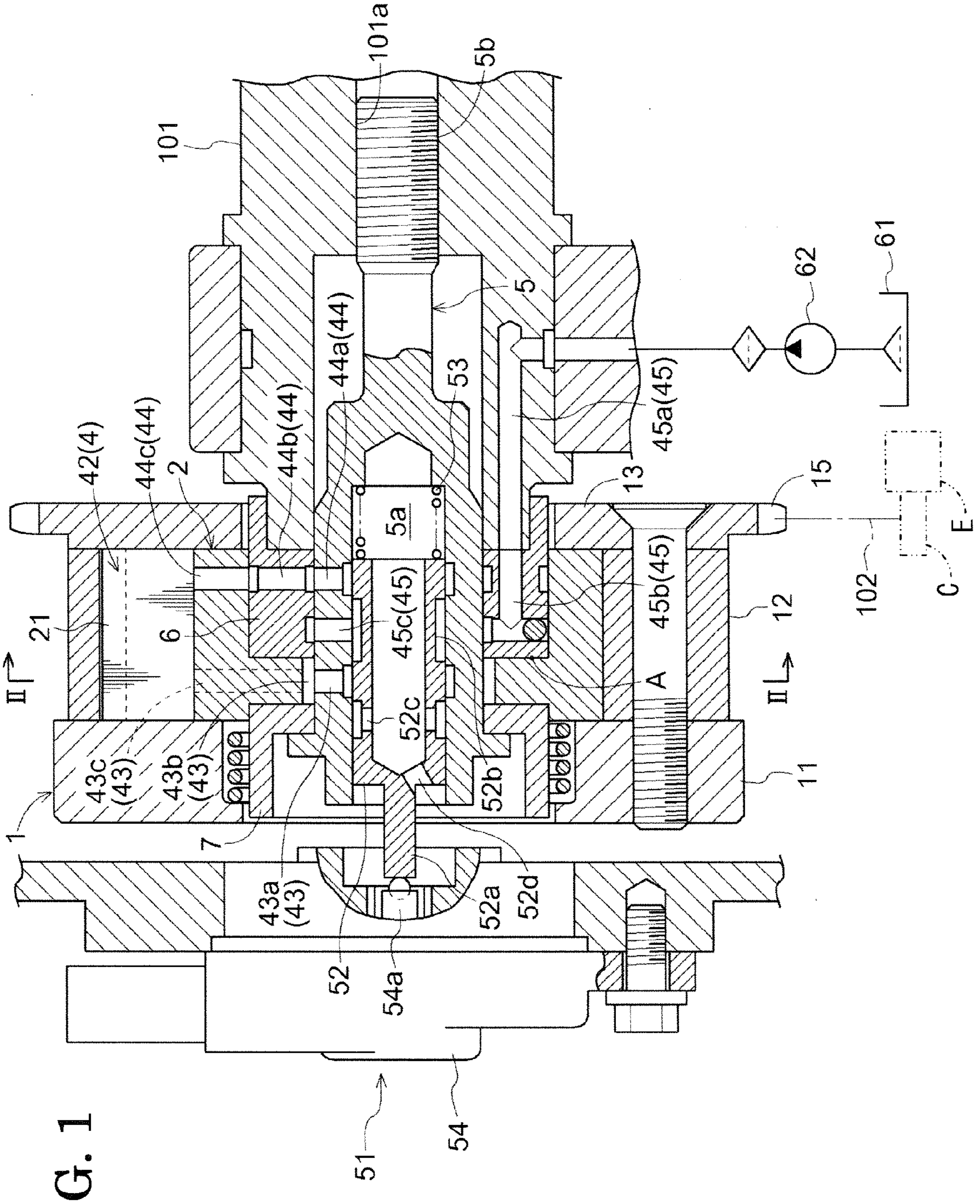
3. The variable valve timing control apparatus according to Claim 1 or 2, wherein a hydraulic fluid is supplied to an outer circumferential side of the driven shaft (5) and is supplied via the intermediate member (6) through the second hydraulic fluid passage (44) to the inner rotor (2).

4. The variable valve timing control apparatus according to any one of Claims 1 to 3, wherein the driven shaft (5) and the intermediate member (6) are made of iron materials and the inner rotor (2) is made of an aluminum material.

5. The variable valve timing control apparatus according to Claim 4, wherein a timing sprocket (15) is arranged at the outer rotor (12) and a bearing portion supporting the timing sprocket (15) is arranged at the intermediate member (6).

6. The variable valve timing control apparatus according to any one of Claims 1 to 4, wherein the driven shaft (101) corresponds to the cam shaft (101) and the intermediate member (6) is press-fitted to the cam shaft (101).

7. The variable valve timing control apparatus according to any one of Claims 1 to 4, wherein the driven shaft (5) corresponds to a bolt (5) screwed with the cam shaft (101), and
   wherein a portion of a control valve (51) switching connection and disconnection between the first hydraulic fluid passage (43) and the second hydraulic fluid passage (44) is accommodated within the bolt (5).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5b
101
5
62
61
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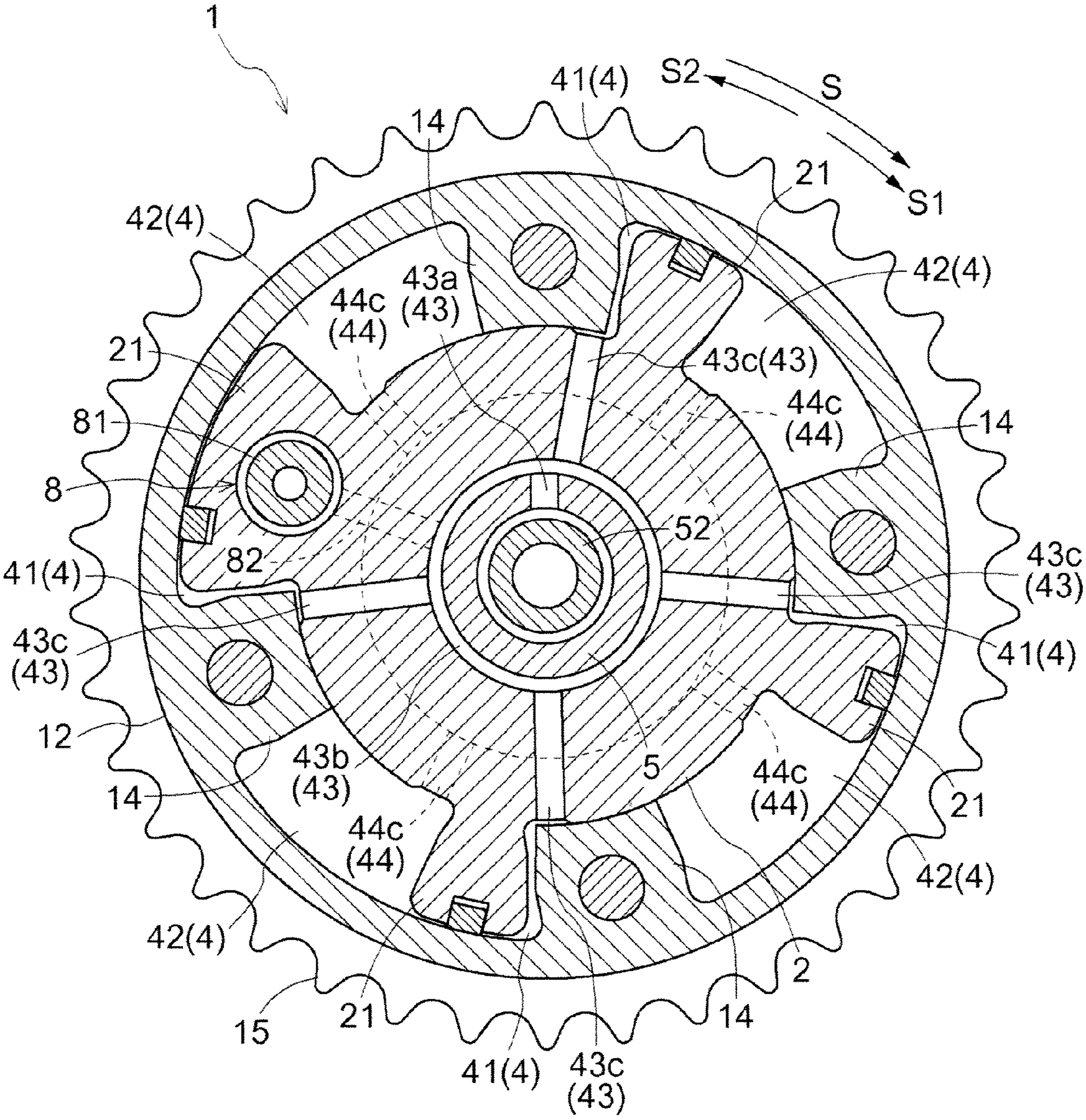
53
45a(45)
42(4)
44c(44)
2
44b(44)
13
15
5a
E
C
102
45c(45)
45b(45)
21
6
12
II
II
A
52c
43c
(43)
43b
(43)
52b
11
1
7
43a
(43)
52a
52d
52
54a
54
51

F I G. 1

F I G. 2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S2
S
S1
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14
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42(4)
42(4)
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44c
(44)
43c(43)
44c
(44)
14
21
81
8
52
82
43c
(43)
41(4)
41(4)
43c
(43)
12
14
43b
(43)
44c
(44)
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(44)
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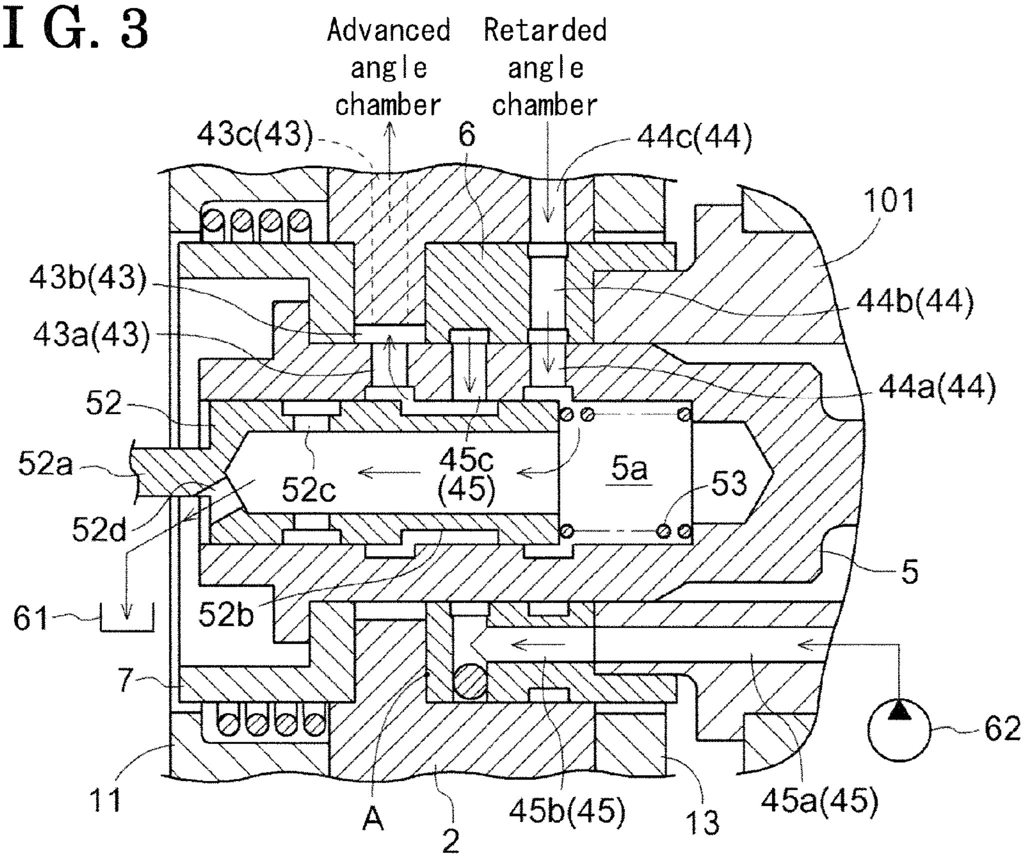
42(4)
2
14
21
15
41(4)
43c
(43)

FIG. 3


Advanced angle chamber
Retarded angle chamber
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6
44c(44)
101
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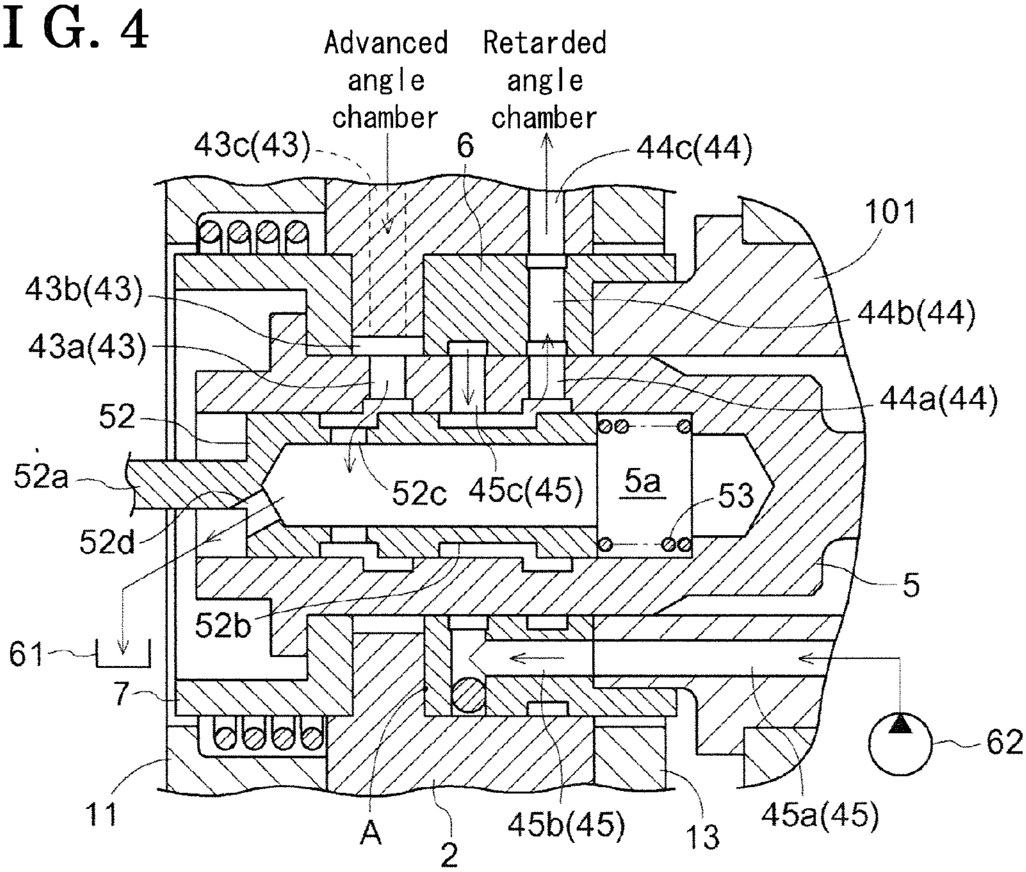
52
52a
45c
(45)
5a
53
52c
52d
5
61
52b
7
62
11
A
2
45b(45)
13
45a(45)

FIG. 4


Advanced angle chamber
Retarded angle chamber
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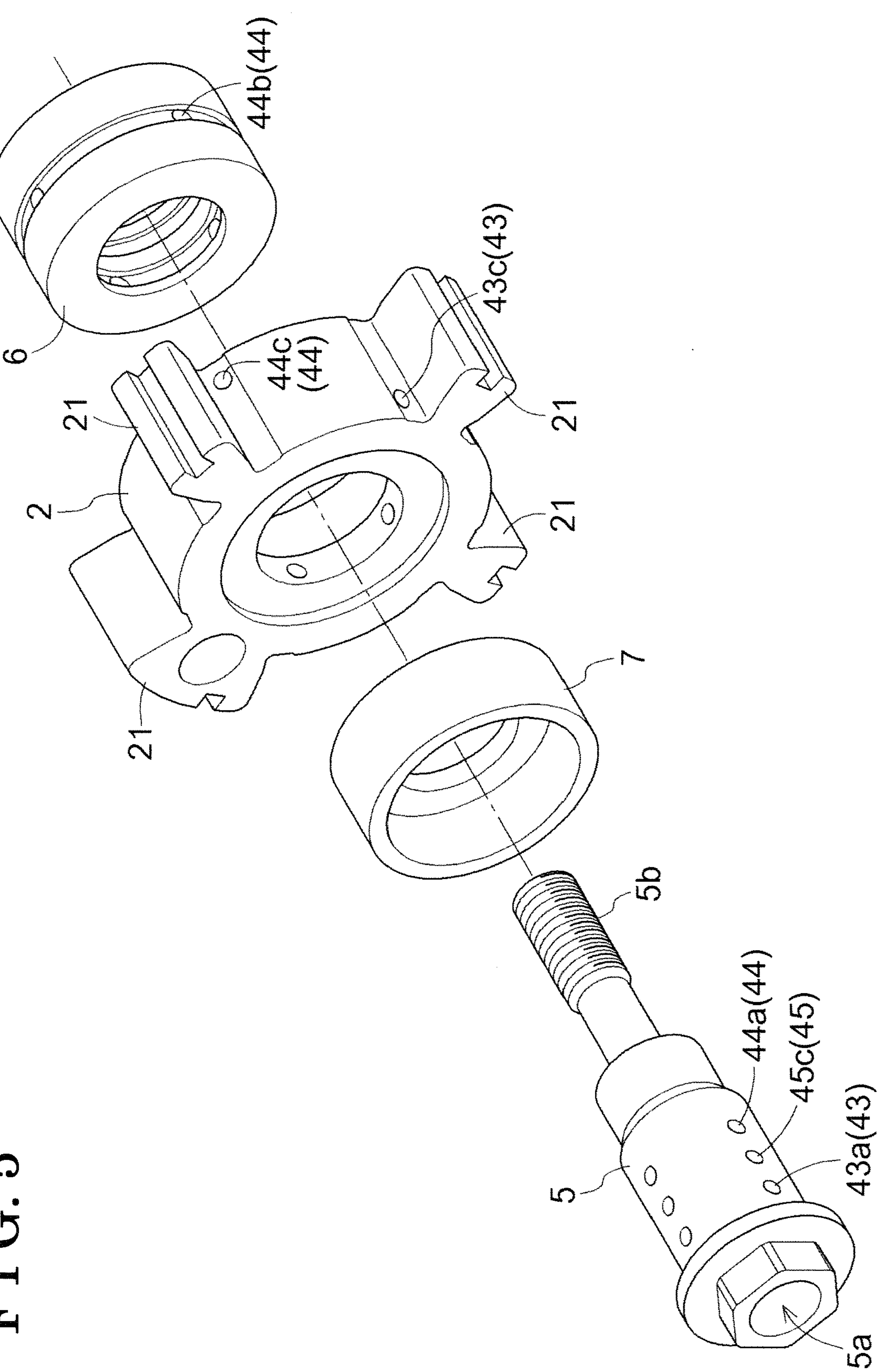
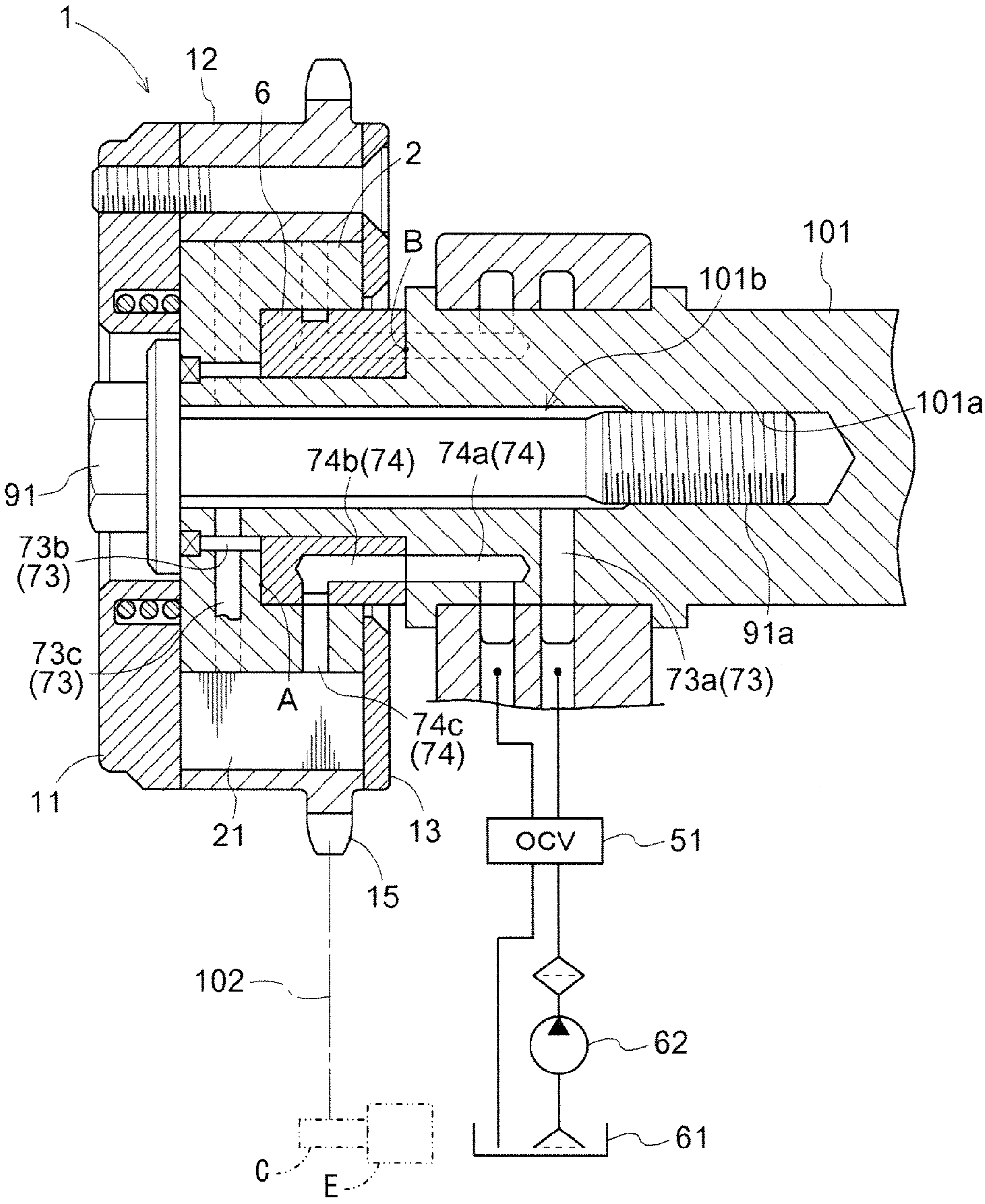
6
44c(44)
101
43b(43)
44b(44)
43a(43)
44a(44)
52
52a
52c
45c(45)
5a
53
52d
5
52b
61
7
62
11
A
2
45b(45)
13
45a(45)

FIG. 5



F I G. 6


1
12
6
2
B
101
101b
101a
91
74b(74)
74a(74)
73b
(73)
73c
(73)
A
74c
(74)
91a
73a(73)
11
21
13
OCV
51
15
102
62
61
C
E

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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 9376

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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	15 December 2011	Clot, Pierre

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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 9376

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