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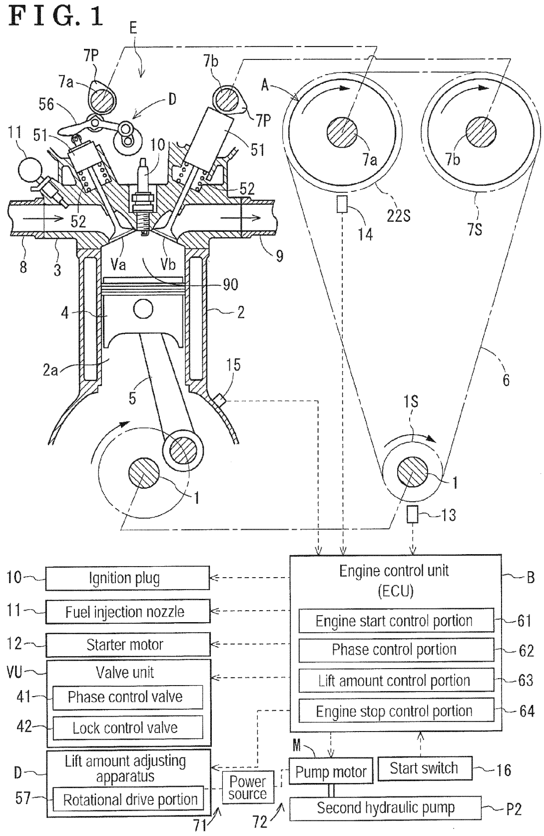
(54) Internal combustion engine

(57) An internal combustion engine (E) includes a lift amount adjusting apparatus (D), a valve opening-closing timing control apparatus (A), a first assist portion (71), a second assist portion (72), and an engine control portion (B). The engine control portion (B) performs a lift amount adjustment control controlling the lift amount adjusting portion (57) to reduce a push force that the valve (Va, Vb) applies on the camshaft (7a, 7b) when the camshaft (7a, 7b) rotates in a case where the engine control portion (B) receives start information of the internal combustion engine (E), controls the phase changing portion (81) thereafter to change the relative rotational phase toward the advanced angle direction (Sa) or toward the retarded angle direction (Sb) on a basis of a predetermined condition, controls the lift amount adjusting portion (57) thereafter to make the lift amount reach a predetermined amount corresponding to the predetermined condition, and drives a starter motor (12) of the internal combustion engine (E) thereafter.

FIG. 1



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Description

TECHNICAL FIELD

[0001] This disclosure generally relates to an internal combustion engine.

BACKGROUND DISCUSSION

[0002] An internal combustion engine including a valve opening-closing timing control apparatus defining valve opening-closing timings of the internal combustion engine is disclosed in JP2007-292027A, hereinafter referred to as Reference 1. More specifically, the internal combustion engine disclosed in Reference 1 includes the valve opening-closing timing control apparatus at an intake camshaft of the internal combustion engine. A hydraulic circuit for controlling the valve opening-closing timings by operating the valve opening-closing timing control apparatus includes a first pump driven by the internal combustion engine and a second pump driven by an electric motor.

[0003] In the internal combustion engine disclosed in Reference 1, the second pump supplies an operation oil to the valve opening-closing timing control apparatus to perform a control that controls the valve opening-closing timings at a time of starting the internal combustion engine until the start operation is completed.

[0004] An internal combustion engine disclosed in JP2007-154748A, hereinafter referred to as Reference 2, includes a valve opening-closing timing control apparatus provided at a camshaft for opening and closing valves of the internal combustion engine. A hydraulic circuit for controlling the valve opening-closing timings by operating the valve opening-closing timing control apparatus includes a first pump driven by the internal combustion engine and a second pump driven by an electric motor.

[0005] At the time of starting the internal combustion engine, the internal combustion engine disclosed in Reference 2 performs a control routine that performs a prestart filling operation, which is an operation to fill one of the advanced angle chamber and the retarded angle chamber of the valve opening-closing timing control apparatus with an operation oil before cranking is started. Then, the control routine shifts to a process of simultaneously supplying operation oil to the advanced angle chamber and to a lock mechanism to perform a lock release operation. After that, the control routine shifts to a process for starting the engine by start cranking.

[0006] An internal combustion engine disclosed in JPH11-13429A, hereinafter referred to as Reference 3, includes a hydraulic accumulator accumulating an operation oil from an oil pump driven by the internal combustion engine. In a state where an appropriate amount of the operation oil is not supplied to the valve opening-closing timing control apparatus, for example, at the time of starting the internal combustion engine, the hydraulic accumulator supplies the operation oil to the valve opening-closing timing control apparatus.

[0007] As the internal combustion engines disclosed in References 1 to 3 indicate, changing valve opening-closing timings and releasing a lock of a lock mechanism by supplying a fluid to the valve opening-closing timing control apparatus before cranking is started at the time of starting the internal combustion engine are considered favorable for enhancing startability of the internal combustion engine.

[0008] Each of the valve opening-closing timing control apparatuses disclosed in Reference 1 and 2 is in a configuration where a driving-side rotating member works together, for example, with a crankshaft or a timing chain. The driving-side rotating member is in a fixed state while a driven-side rotating member rotates when the fluid is supplied to change the valve opening-closing timings in an operation to change valve opening-closing timings by controlling the valve opening-closing timing control apparatus.

[0009] The driven-side rotating member is directly connected to the camshaft and the camshaft works together with a mechanism for opening and closing the valves. As a result, when rotating the driven-side rotating member, a powerful driving force is required for rotating the driven-side rotating member against the biasing force of the springs that bias the valves to lift.

[0010] Accordingly, each of the internal combustion engines disclosed in References 1 and 2 includes a powerful electric motor to drive a fluid pressure pump driven by an electric motor. Similarly, the internal combustion engine disclosed in Reference 3 includes an accumulator, which may be large in size in order to increase pressure of the fluid accumulated in the accumulator. Increase in size of the devices for controlling the valve opening-closing timing control apparatus and consuming and wasting a large amount of energy are considered as drawbacks that need to be resolved in the internal combustion engine according to each of References 1 to 3.

[0011] A need thus exists for an internal combustion engine that is restrained from increasing in size of a configuration for adjusting valve opening-closing timings before cranking of the internal combustion engine starts and for rationally configuring the internal combustion engine that is restrained from wasting energy when adjusting the valve opening-closing timings.

SUMMARY

[0012] An internal combustion engine includes a lift amount adjusting apparatus driven by a lift amount adjusting portion and adjusting a lift amount of a valve at a combustion chamber when a camshaft for opening and closing the valve of the internal combustion engine rotates, a valve opening-closing timing control apparatus including a driving-side rotating member synchronously rotating with a crankshaft of the internal combustion engine, a driven-side rotating member coaxially positioned relative to the driving-side rotating member and integrally rotating with the camshaft, and a lock mechanism retaining a relative rotational phase between the driving-side rotating member and the driven-side rotating member at a predetermined lock phase, the valve opening-closing timing control apparatus driven by a phase changing portion and adjusting opening-closing timings of the valve by selectively changing the relative rotational phase between the driving-side rotating member and the driven-side rotating member toward an advanced angle direction or toward a retarded angle direction that is different from the advanced angle direction, a first assist portion configured to adjust the lift amount adjusted by the lift amount adjusting portion while the internal combustion engine is in a stopped state, a second assist portion configured to change the relative rotational phase changed by the phase changing portion while the internal combustion engine is in the stopped state, and an engine control portion performing a lift amount adjustment control controlling the lift amount adjusting portion to reduce a push force that the valve applies on the camshaft when the camshaft rotates in a case where the engine control portion receives start information of the internal combustion engine, controlling the phase changing portion then to change the relative rotational phase toward the advanced angle direction or toward the retarded angle direction on a basis of a predetermined condition, controlling the lift amount adjusting portion then to make the lift amount reach a predetermined amount corresponding to the predetermined condition, and driving a starter motor of the internal combustion engine after the engine control portion controls the lift amount adjusting portion to make the lift amount reach the predetermined amount corresponding to the predetermined condition.

[0013] Accordingly, when the engine control portion receives the start information of the internal combustion engine, the engine control portion controls the lift amount adjusting portion so that the first assist portion performs the lift amount adjustment control so as to reduce the push force that the valve applies on the camshaft when the camshaft rotates. Then, the engine control portion controls the phase changing portion next so that the second assist portion changes the relative rotational phase of the valve opening-closing timing control apparatus toward the advanced angle direction or toward the retarded angle direction on the basis of the predetermined condition. Then, the engine control portion controls the lift amount adjusting portion next so that the first assist portion makes the lift amount reach the predetermined amount corresponding to the predetermined condition. Then, after the engine control portion controls the lift amount adjusting portion so that the first assist portion makes the lift amount reach the predetermined amount corresponding to the predetermined condition, the engine control portion drives the starter motor of the internal combustion engine so as to start cranking so as to start the internal combustion engine. As a result, at the time at which the valve opening-closing timing control apparatus is controlled so as to change the relative rotational phase, a driving force for rotating the driven-side rotating body is reduced by decreasing the lift amount of the valve. Accordingly, a small size actuator using small amount of energy may be used instead of using, for example, a large size actuator using large amount of energy in order to change the starting phase of the valve opening-closing timing control apparatus. By making the lift amount reach the predetermined amount corresponding to the predetermined condition after the engine control portion controls the phase changing portion and sets the relative rotational phase of the valve opening-closing timing control apparatus at the phase suitable for starting the internal combustion engine, cranking is started in a state where the valve is appropriately opened and closed for starting the internal combustion engine. Thus, the internal combustion engine is configured such that the internal combustion engine is restrained from increasing in size of a configuration for adjusting the valve opening-closing timings before the cranking of the internal combustion engine starts. Further, the internal combustion engine is configured such that the internal combustion engine is restrained from wasting energy when adjusting the valve opening-closing timings.

[0014] According to another aspect of this disclosure, the internal combustion engine further includes a temperature sensor detecting temperature of the internal combustion engine and a rotational phase sensor detecting the relative rotational phase of the valve opening-closing timing control apparatus. Further, the aforementioned predetermined condition is temperature of the internal combustion engine. The lock mechanism of the internal combustion engine is configured to retain the relative rotational phase between the driving-side rotating member and the driven-side rotating member at minimum of two different lock phases including an intermediate lock phase and a retarded angle side lock phase that is different from the intermediate lock phase, the intermediate lock phase being suitable for starting the internal combustion engine when the temperature of the internal combustion engine is equal to or lower than a predetermined temperature and the retarded angle side lock phase being suitable for starting the internal combustion engine when the temperature of the internal combustion engine is higher than the predetermined temperature. The engine control portion of the internal combustion engine controls the phase changing portion to define the relative rotational phase on the basis of detected results from the temperature sensor and the rotational phase sensor, controls the phase changing portion to change the relative rotational phase to be at the retarded angle side lock phase when the engine control portion determines that the temperature of the internal combustion engine is higher than the predetermined temperature and determines that the relative rotational phase is at the intermediate lock phase, and controls the phase changing portion to change the relative rotational phase to be at the intermediate lock phase when the engine control portion determines that the temperature of the internal combustion engine is equal to or lower than the predetermined temperature and determines that the relative rotational phase is at the retarded angle side lock phase.

[0015] Accordingly, the cranking is performed so as to start the internal combustion engine with the valve opening-closing timings suitable for a state in which the internal combustion engine is determined as cold or for a state in which the internal combustion engine is determined as warm when the engine control portion receives the start information of the internal combustion engine.

[0016] According to further aspect of this disclosure, the driven-side rotating member of the internal combustion engine is internally accommodated by the driving-side rotating member to provide a fluid pressure chamber partitioned into an advanced angle chamber and a retarded angle chamber at a position between the driven-side rotating member and the driving-side rotating member. The phase changing portion of the internal combustion engine changes the relative rotational phase toward the advanced angle direction by supplying a fluid to the advanced angle chamber and changes the relative rotational phase toward the retarded angle direction different from the advanced angle direction by supplying the fluid to the retarded angle chamber. The second assist portion of the internal combustion engine is configured with an accumulator accumulating the fluid in a pressurized state or with an electric fluid pressure pump discharging the fluid by electric power.

[0017] Accordingly, the lift amount of the valve is already decreased at the time at which the relative rotational phase of the valve opening-closing timing control apparatus is controlled toward the advanced angle direction or toward the retarded angle direction. As a result, in a case where the second assist portion is configured with the accumulator, the size of the accumulator is restrained from increasing and in a case where the second assist portion is configured with the electric fluid pressure pump, a small size electric motor may be used to drive the electric fluid pressure pump instead of using a large size electric motor.

[0018] According to another aspect of this disclosure, the retarded angle side lock phase is defined at a phase at most retarded angle and phases close to the most retarded angle.

[0019] Accordingly, in a case where the internal combustion engine is started in a state in which the internal combustion engine is determined as cold, the lock mechanism locks the relative rotational phase at the most advanced angle or the phases close to the most retarded angle so that the internal combustion engine is started in a favorable state.

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:

Fig. 1 is a schematic view drawing illustrating an engine, a valve opening-closing timing control apparatus and a control system of the internal combustion engine according to an embodiment disclosed here;

Fig. 2 is a cross-sectional view drawing illustrating the valve opening-closing timing control apparatus and the configuration for controlling the valve opening-closing timing control apparatus of the internal combustion engine according to the embodiment disclosed here;

Fig. 3 is a cross-sectional view drawing taken along line III-III in Fig. 2;

Fig. 4 is a cross-sectional view drawing taken along line IV-IV in Fig. 2 illustrating the valve opening-closing timing control apparatus in a state where the lock members are in a lock release state;

Fig. 5 is a cross-sectional view drawing taken along line V-V in Fig. 2 illustrating the valve opening-closing timing control apparatus in a state where the lock members are locked at the most retarded angle;

Fig. 6 is a drawing illustrating a lift amount adjusting apparatus of the internal combustion engine according to the embodiment disclosed here in a state in which the lift amount is set at maximum;

Fig. 7 is a drawing illustrating the lift amount adjusting apparatus of the internal combustion engine according to the embodiment disclosed here in a state in which the lift amount is set at minimum;

Fig 8 is a flowchart illustrating an engine start control of the internal combustion engine according to the embodiment disclosed here; and

Fig. 9 is a cross-sectional view drawing illustrating the valve opening-closing timing control apparatus and the configuration for controlling the valve opening-closing timing control apparatus of the internal combustion engine according to an alternative embodiment disclosed here.

DETAILED DESCRIPTION

[0021] An internal combustion engine according to an embodiment will be described referring to the attached drawings. A basic configuration of the internal combustion engine according to the embodiment will be described first. As illustrated in Figs. 1 and 2, an engine E, which serves as the internal combustion engine, includes a valve opening-closing control apparatus A coaxially positioned relative to an intake camshaft 7a and synchronously rotating with a crankshaft 1 for controlling timings to open and close an intake valve Va. The intake camshaft 7a serves as the camshaft and the intake valve Va serves as the valve.

[0022] The engine E is configured as a four-cycle engine in which a cylinder head 3 connects to a cylinder block 2 so as to position the cylinder head 3 on top of the cylinder block 2, plural cylinder bores 2a formed in the cylinder block 2 slidably accomodates a piston 4 in each of the cylinder bores 2a, and each of the pistons 4 connects to the crankshaft 1 via a connecting rod 5.

[0023] The cylinder head 3 includes the intake valve Va taking air into a combustion chamber 90 and an exhaust valve Vb exhausting combustion gas out of the combustion chamber 90. The cylinder head 3 further includes the intake camshaft 7a controlling the intake valve Va and an exhaust camshaft 7b controlling the exhaust valve Vb. A timing chain 6 is entrained around an output sprocket 1S of the crankshaft 1, a driving sprocket 22S of an outer rotor 20 of the variable valve control apparatus A, and a shaft sprocket 7S of the exhaust camshaft 7b. The outer rotor 20 is an example of a driving-side rotating member.

[0024] The cylinder head 3 is connected with an intake manifold 8 supplying air into the combustion chamber 90 via the intake valve Va and with an exhaust manifold 9 sending exhaust gas out of the combustion chamber 90 via the exhaust valve Vb. The cylinder head 3 includes an ignition plug 10 and a fuel injection nozzle 11. A starter motor 12 applying a rotational force to the crankshaft 1 is provided at a position outside of the engine E.

[0025] The engine E is configured as the four-cycle engine in which the plural pistons 4 perform intake, compression, combustion and exhaust processes sequentially. Linked to these processes, the rotational force applied by the crankshaft 1 is transmitted to the intake camshaft 7a and the exhaust camshaft 7b via the timing chain 6. Accordingly, the intake valve Va and the exhaust valve Vb are opened and closed in synchronization with the rotation of the crankshaft 1.

[0026] In addition, the engine E includes a lift amount adjusting apparatus D adjusting the lift amount of the intake valve Va at the time at which the intake camshaft 7a rotates. The lift amount adjusting apparatus D is controlled on the basis, for example, of rotation speed of the engine E and the load on the engine E during a period during which the engine E is in operation.

[0027] Alternatively, the engine E may be configured with the valve opening-closing timing control apparatus A including the exhaust camshaft 7b serving as the camshaft for controlling opening and closing timing of the exhaust valve Vb serving as the valve. Further, instead of including the driving sprocket 22S on the outer rotor 20, the outer rotor 20 may include a timing pulley for transmitting the rotational force of the crankshaft 1 with a timing belt. Similarly, a gear may be formed on an outer surface of the outer rotor 20 so as to transmit the rotational force of the crankshaft 1 by using a gear train.

[0028] The engine E is for mounting, for example, on a passenger vehicle. The engine E and the valve opening-closing timing control apparatus A are controlled by an engine control unit B, which is an electronic control unit (ECU). The engine control unit B serves as the engine control portion. The engine E includes a crank sensor 13 detecting a rotational attitude, or a rotational position, of the crankshaft 1. The engine E further includes a rotational phase sensor 14 at a position close to the valve opening-closing timing control apparatus A. The rotational phase sensor 14 detects the relative rotational phase between the outer rotor 20 and an inner rotor 30. In addition, the engine E includes a temperature sensor 15 detecting the temperature of the engine E.

[0029] The valve opening-closing timing control apparatus A of the internal combustion engine according to the embodiment will be described next. As illustrated in Figs. 1 to 5, the valve opening-closing timing control apparatus A includes the outer rotor 20, which serves as the driving-side rotating member, synchronously rotating with the crankshaft 1 and the inner rotor 30, which serves as a driven-side rotating member, connected to the intake camshaft 7a with a connecting bolt 33. The outer rotor 20 and the inner rotor 30 are coaxially positioned relative to the rotary axis X of the intake camshaft 7a and are relatively rotatable about the rotary axis X. The valve opening-closing timing control apparatus A is configured to control the timings to open and close the intake valve Va by shifting, or changing, the relative rotational phase between the outer rotor 20 and the inner rotor 30. Hereinafter, the relative rotational phase refers to the relative rotational phase between the outer rotor 20 and the inner rotor 30.

[0030] The outer rotor 20 is configured with a rotor body 21, a rear block 22 and a front plate 23. The rotor body 21 is formed in a hollow cylindrical form. The rear block 22 is positioned so as to be in contact with one end of the end portions of the rotor body 21, the end portions spaced apart in a direction that conforms to the rotary axis X. The front plate 23 is positioned so as to be in contact with the other end of the end portions of the rotor body 21, the end portions spaced apart in the direction that conforms to the rotary axis X. The rotor body 21, the rear block 22, and the front plate 23 are retained by using a multiple number of fastening bolts 24 so as to form the outer rotor 20. The driving sprocket 22S transmitting the rotational force of the crankshaft 1 is formed at the outer circumference of the rear block 22. The rotor body 21 includes an inner wall surface 21A formed in a hollow cylindrical form integrally formed with a multiple number of protruding portions 21T protruding toward the rotary axis X, which is in a radially inward direction.

[0031] One of the protruding portion 21 T is formed with a pair of guide grooves 21 G extending in a radial direction relative to the rotary axis X. A lock member 25 formed in a plate form is inserted into each of the guide grooves 21 G so as to project from and retract into the guide groove 21 G. Further, the rotor body 21 includes lock springs 26 arranged inside the rotor body 21. Each of the lock springs 26 biases the lock member 25 toward the rotary axis X. A first lock mechanism L1 is configured with one of the lock members 25 and one of the lock springs 26 biasing the mentioned one of the lock members 25 in a protruding direction of the mentioned one of the lock member 25. A second lock mechanism L2 is configured with the other lock member 25 and the other lock spring 26 biasing the other lock member 25 in the protruding direction of the other lock member 25. Note that a lock mechanism L is a broader concept including the first lock mechanism L1 and the second lock mechanism L1. The form of the lock members 25 is not limited to the plate form. For example, each of the lock members 25 may be formed in a rod form.

[0032] The inner rotor 30 includes an inner circumferential surface 30S, which is formed in a form of an inner surface of a hollow cylinder coaxially formed with the rotary axis X, and an outer circumferential surface 30T with the center at the rotary axis X. A multiple number of vanes 31 are fitted into the outer circumferential surface 30T so as to protrude radially outward. A flange portion 32 is formed at one end portion of the end portions of the inner rotor 30, the end portions spaced apart in the direction conforming to the rotary axis X. The connecting bolt 33 is inserted through a through-hole extending at the inner circumference of the flange portion 32 so as to connect the inner rotor 30 to the intake camshaft 7a.

[0033] The inner rotor 30 is fitted in, or internally accommodated by, the outer rotor 20. Accordingly, the fluid pressure chambers C are formed at regions surrounded by the inner surface of the rotor body 21, which includes the inner wall surface 21A formed in the hollow cylindrical form and the protruding portions 21T, and the outer circumferential surface 30T of the inner rotor 30. Each of the fluid pressure chambers C is partitioned by the vane 31 so as to form an advanced angle chamber Ca and a retarded angle chamber Cb. The advanced angle chamber Ca, the retarded angle chamber Cb, and the vane 31 forms a phase changing portion 81. The phase changing portion 81 is a hydraulically operated portion configured by including the advanced angle chamber Ca, the retarded angle chamber Cb, and the vane 31 so as to change the relative rotational phase with hydraulic pressure. The inner rotor 30 is formed with advanced angle passages 34, retarded angle passages 35, and a lock release passage 36. The advanced angle passages 34 communicate with the advanced angle chambers Ca. The retarded angle passages 35 communicate with the retarded angle chambers Cb.

[0034] An intermediate lock recess 37 and a most retarded angle lock recess 38 are formed on the outer circumferential surface 30T of the inner rotor 30. The intermediate lock recess 37, which is formed in a form of a groove, is configured such that each of the lock member 25 of the first lock mechanism L1 and the lock member 25 of the second lock mechanism L2 selectively engage. The most retarded angle lock recess 38 is configured such that the lock member 25 of the second lock mechanism L2 selectively engages. The intermediate lock recess 37 and the most retarded angle lock recess 38 are formed so as to recess toward the rotary axis X relative to the outer circumferential surface 30T of the inner rotor 30. The intermediate lock recess 37 communicates with the lock release passage 36. The most retarded angle lock recess 38 communicates with the advanced angle passage 34.

[0035] In a state where the lock member 25 of the first lock mechanism L1 and the lock member 25 of the second lock mechanism L2 are engaged with the intermediate lock recess 37, which is the state illustrated in Fig. 3, the lock members 25 are in contact with the end portions of the intermediate lock recess 37 spaced apart in the circumferential direction so as to retain the relative rotational phase at an intermediate lock phase. By supplying an operation oil, which is an example of a fluid, to the lock release passage 36 at the intermediate lock phase, two lock members 25 disengage from the intermediate lock recess 37 against the biasing force of the lock springs 26 and are retained in a lock release state, which is the state illustrated in Fig. 4. The intermediate lock phase refers to any phase intermediate between the most advanced angle phase and the most retarded angle phase excluding the most advanced angle phase and the most retarded angle phase, and not limited to the phase at the middle of the region where the relative rotational phase is configured to vary.

[0036] In a state where the lock member 25 of the second lock mechanism L2 is engaged with the most retarded angle lock recess 38, which is illustrated in Fig. 5, the relative rotational phase is retained at the most retarded angle phase, which is the most retarded angle lock phase. By supplying the operation oil to the advanced angle passage 34 at the most retarded angle phase, which is an example of a retarded angle side lock phase, the lock member 25 of the fist lock mechanism L1 disengages from the most retarded angle lock recess 38 against the biasing force of the lock spring 26 and is retained in the lock release state so that the relative rotational phase shifts in an advanced angle direction Sa.

[0037] A torsion spring 27 is provided to extend between the rear block 22 of the outer rotor 20 and the inner rotor 30. The torsion spring 27 applies biasing force to the valve opening-closing timing control apparatus A, for example, from the most retarded angle phase until at least an intermediate lock phase is established.

[0038] In the valve opening-closing timing control apparatus A, the outer rotor 20 rotates in a drive rotational direction S by a driving force transmitted from the timing chain 6. The direction in which the inner rotor 30 rotates in the same direction as the drive rotational direction S relative to the outer rotor 20 is referred to as the advanced angle direction Sa. The rotational direction opposite to the advanced angle direction Sa is referred to as a retarded angle direction Sb. In the valve opening-closing timing control apparatus A, the crankshaft 1 and the intake camshaft 7a are defined in a relation such that the compression ratio of an intake air is increased with the increase of a phase shift amount when the relative rotational phase shifts in the advanced angle direction Sa and the compression ratio of the intake air is decreased with the increase of the phase shift amount when the relative rotational phase shifts in the retarded angle direction Sb.

[0039] The relative rotational phase shifts, or changes, in the advanced angle direction Sa when the operation oil, which is an example of the fluid, is supplied to the advanced angle chamber Ca. The relative rotational phase shifts, or changes, in the retarded angle direction Sb when the operation oil is supplied to the retarded angle chamber Cb. When the vane 31 reaches a movement end, which is a rotational limit about the rotary axis X, in the advanced angle direction Sa, the relative rotational phase is referred to as at the most advanced angle phase. When the vane 31 reaches the movement end, which is the rotational limit about the rotary axis X, in the retarded angle direction Sb, the relative rotational phase is referred to as at the most retarded angle phase. In the internal combustion engine according to the embodiment, the most retarded angle lock phase, which is an example of the retarded angle side lock phase, is reached when the relative rotational phase reaches the most retarded angle phase and the internal combustion engine according to the embodiment is configured to be retained at the most retarded angle phase.

[0040] The most retarded angle phase is a phase included in the concept of a retarded angle side phase and the retarded angle side phase includes a phase at the most retarded angle phase and phases close to the most retarded angle. The most retarded angle phase is not limited to the phase at which the vane 31 is at the movement end in the retarded angle direction and includes the phases at which the vane 31 is at positions close to the movement end in the retarded angle direction. Accordingly, the retarded angle side lock phase includes the most retarded angle lock phase and the phases close to the most retarded angle, which are the phases shifted toward the intermediate phase relative to the most retarded angle phase. Similarly, the most advanced angle phase is not limited to the phase at which the vane 31 is at the movement end in the advanced angle direction and includes the phases at which the vane 31 is at positions close to the movement end in the advanced angle direction.

[0041] The valve opening-closing timing control apparatus A according to this disclosure may be alternatively configured such that the lock mechanism L retains the relative rotational phase at the most retarded angle lock phase illustrated in Fig. 5 and additionally at a phase close to the most retarded angle lock phase at which the inner rotor 30 is shifted in the advanced angle direction Sa relative to the most retarded angle lock phase illustrated in Fig. 5 when the lock mechanism L retains the relative rotational phase at the retarded angle side lock phase. In other words, the retarded angle side lock phase may be considered as a predetermined retarded angle side phase region. Accordingly, for example, the valve opening-closing timing control apparatus A may be configured such that the inner rotor 30 is formed with a multiple number of recesses so that the relative rotational phase may be retained at two or more lock phases within the retarded angle side phase region.

[0042] Further, the valve opening-closing timing control apparatus A according to this disclosure is alternatively configured such that the lock mechanism L retains the relative rotational phase at the intermediate lock phase illustrated in Fig. 3 and additionally at a phase at which the inner rotor 30 is shifted in the advanced angle direction Sa or in the retarded angle direction Sb relative to the rotational phase illustrated in Fig. 3. In other words, the intermediate lock phase may be considered as a predetermined intermediate phase region. Accordingly, for example, the valve opening-closing timing control apparatus A may be configured such that the inner rotor 30 is formed with a multiple number of recesses so that the relative rotational phase may be retained at two or more lock phases within the intermediate phase region.

[0043] A valve unit VU of the internal combustion engine according to the embodiment will be described next. The valve unit VU includes a phase control valve 41 and a lock control valve 42 accommodated in a unit case. The valve unit VU is configured such that a passage forming shaft portion 43, which is integrally formed with the unit case, is inserted into the inner circumferential surface 30S of the inner rotor 30. Circumferentially formed groove portions 45 communicating with ports of the phase control valve 41 and the lock control valve 42 are formed on the outer circumference of the passage forming shaft portion 43. Plural ring-shaped seals 44 are provided between the outer circumference of the passage forming shaft portion 43 and the inner circumferential surface 30S of the inner rotor 30 to separate the circumferential groove portions 45 from one another.

[0044] The engine E includes a first hydraulic pump P1, which is driven by the engine E so as to supply oil in an oil pan as the operation oil, and a second hydraulic pump P2, which is driven by a pump motor M powered by electricity. The second hydraulic pump P2 serves as the electric fluid pressure pump. The engine E is formed with passages in which the operation oil is supplied from either one of the first hydraulic pump P1 or the second hydraulic pump P2 to the phase control valve 41 and to the lock control valve 42. In addition, the engine E includes a second assist portion 72 configured with the pump motor M, the second hydraulic pump P2 driven by the pump motor M, and a power source PS supplying power to the pump motor M. The second assist portion 72 is configured to operate the phase changing portion 81 to hydraulically change, or shift, the relative rotational phase even in a state where the engine E is stopped.

[0045] The engine control unit B controls the phase control valve 41 that operates electromagnetically and the lock control valve 42 that operates electromagnetically to control the timings to intake air. Operations of the valve opening-closing timing control apparatus A will be described in detail later in this disclosure. The phase control valve 41 and the lock control valve 42 are accommodated in the valve unit VU to form a single unit. A portion of the valve unit VU is inserted into the valve opening-closing timing control apparatus A.

[0046] The lift amount adjusting apparatus D will be described next. As Figs. 1, 6, and 7 illustrate, the intake valve Va includes a valve system 50 and a lash adjuster 51 positioned at the upper end portion of the valve system 50. The intake valve Va is biased by a valve spring 52 in a closing direction. The top end portion of the lash adjuster 51 shifts in an upward direction when the lash adjuster 51 is supplied with the operation oil. The lash adjuster 51 is configured to absorb shock at the time at which the cam portion 7P of the intake camshaft 7a makes contact with the rocker arm 56 by adjusting the clearance between the cam portion 7P and the rocker arm 56 and between the contact body 56A and the contact roller 53 while the top end portion of the lash adjuster 51 shifting downward and discharging the operation oil that is internally contained. A contact roller 53 is rotatably supported at the top end portion of each of the lash adjusters 51.

[0047] The lift amount adjusting apparatus D includes a support arm 55, which is rotatable at a rotary axis Q as the center of rotation, and a rocker arm 56, which is supported at a swing axis R and swingable at the swing axis R as the center of a swinging motion. The number of rocker arms 56 is equal to the number of the intake valves Va. Each of the rocker arms 56 is formed with a contact body 56A at an end portion of the rocker arm 56. An intermediate roller 56B is rotatably supported at an intermediate portion of each of the rocker arms 56.

[0048] In addition, the lift amount adjusting apparatus D includes a rotational drive portion 57, which is powered by electricity, so as to rotate the support arm 55 with the rotary axis Q as the center of rotation. The rotational drive portion 57 serves as the lift amount adjusting portion. The rotational drive portion 57, which is a single unit, and the power source PS supplying electricity to the rotational drive portion 57 configures a first assist portion 71. The first assist portion 71 is configured to adjust the lift amount of the intake valve Va during a period during which the engine E is stopped.

[0049] In the lift amount adjusting apparatus D, the rocker arm 56 swings with the rotary axis Q as the center of a swinging motion by the cam portion 7P of the intake camshaft 7a making contact with the intermediate roller 56B. When the rocker arm 56 swings, the contact body 56A is made to contact with the contact roller 53 of the intake valve Va so as to perform an operation to open the intake valve Va against the biasing force of the valve spring 52.

[0050] In order to adjust the lift amount, the support arm 55 is made to rotate with the rotary axis Q as the center of rotation and changes the position of the swing axis R so as to change the swinging amount of the rocker arm 56 when the cam portion 7P of the intake camshaft 7a makes contact. More specifically, by positioning the swing axis R at a maximum position Max, the lift amount of the intake valve Va becomes a maximum lift amount Tmax and by positioning the swing axis R at a minimum position Min, the lift amount of the intake valve Va becomes a minimum lift amount Tmin.

[0051] Upon the arrangement described above, in a case where the intake camshaft 7a is rotated and opens the intake valve Va with the push force applied by the cam portion 7P of the intake camshaft 7a, the intake camshaft 7a receives a large reaction force in order to operate the intake valve Va against the biasing force of the valve spring 52. In a case where the lift amount adjusting apparatus D performs a control that reduces the lift amount, the operating amount of the intake valve Va becomes small and the compression amount of the valve spring 52 becomes small so that the reaction force that the intake camshaft 7a receives becomes small.

[0052] The configuration of the lift amount adjusting apparatus D is not limited to the configuration illustrated in Figs. 6 and 7. For example, a lift amount adjusting apparatus disclosed in JP2007-170180A or in JP2009-85136A may be used instead. In the internal combustion engine E according to the embodiment, the lift amount adjusting apparatus D is provided for adjusting the lift amount of the intake valve Va alone, however, alternatively, an additional lift amount adjusting apparatus D may be provided for adjusting the lift amount of the exhaust valve Vb. In such case, the exhaust valve Vb serves as the valve and the exhaust camshaft 7b serves as the camshaft.

[0053] The engine control unit B of the internal combustion engine according to the embodiment will be described next. The engine control unit B controls the engine E by software by, for example, using a microprocessor and a digital signal processor (DSP). The engine control unit B includes an engine start control portion 61, a phase control portion 62, a lift amount control portion 63, and an engine stop control portion 64. Each of the engine start control portion 61, the phase control portion 62, the lift amount control portion 63, and the engine stop control portion 64 is a software portion of the engine control unit B. Alternatively, each of the engine start control portion 61, the phase control portion 62, the lift amount control portion 63, and the engine stop control portion 64 may be provided as a hardware portion or a combination of software and hardware.

[0054] The engine control unit B includes input systems receiving information from a crank sensor 13, a rotational phase sensor 14, a temperature sensor 15, and a start switch 16. The engine control unit B further includes output systems sending control information to the ignition plug 10, the fuel injection nozzle 11, the starter motor 12, the phase control valve 41 of the valve unit VU, the lock control valve 42 of the valve unit VU, the rotational drive portion 57 of the lift amount adjusting apparatus D, and the pump motor M.

[0055] The engine start control portion 61 is basically configured to receive start information from the start switch 16 so as to operate the starter motor 12 and control the ignition plug 10 and the fuel injection nozzle 11 so as to start the engine E. More specifically, the engine start control portion 61 performs a control to define the relative rotational phase of the valve opening-closing timing control apparatus A at an appropriate phase for starting the engine E prior to cranking by the starter motor 12 on the basis of the temperature of the engine E detected by the temperature sensor 15 and the relative rotational phase information detected by the rotational phase sensor 14. The mentioned control in detail will be described later in the disclosure.

[0056] The phase control portion 62 controls the valve unit VU in a state where the rotational phase sensor 14 feeds back the relative rotational phase information to the phase control portion 62 so as to set the relative rotational phase of the valve opening-closing timing control apparatus A to a phase suitable for the time of starting the engine E on the basis of, for example, the rotation speed of the engine E and a load on the engine E.

[0057] The lift amount control portion 63 adjusts the lift amount of the intake valve Va controlled by the lift amount adjusting apparatus D by controlling the rotational drive portion 57 at the time of starting the engine E on the basis of, for example, the rotation speed of the engine E and the load on the engine E, similarly to the phase control portion 62.

[0058] At the time of stopping the engine E, the engine stop control portion 64 controls the ignition plug 10 and the fuel injection nozzle 11 so as to stop the engine E after the relative rotational phase of the valve opening-closing timing control apparatus A is defined at a predetermined phase.

[0059] The control operation of the internal combustion engine according to the embodiment will be described next. The engine stop control portion 64 performs an idle stop control and a manual stop control. The idle stop control is a control that automatically stops the engine E when the driver presses the bake pedal. The manual stop control is a control that stops the engine E by the driver operating the start switch 16 to OFF. In the idle stop control, the relative rotational phase of the valve opening-closing timing control apparatus A is changed, or shifted, to the most retarded angle phase and after the valve opening-closing timing control apparatus A is locked at the most retarded angle phase, which is illustrated in Fig. 5, the engine E is stopped. In the manual stop control, the relative rotational phase of the valve opening-closing timing control apparatus A is changed, or shifted, to the intermediate phase and after the valve opening-closing timing control apparatus A is locked at the intermediate phase, which is illustrated in Fig. 3, the engine E is stopped.

[0060] In a case where the start switch 16 is operated to OFF in a state where the engine E is stopped by the idle stop control, the relative rotational phase is retained in a state where the relative rotational phase is locked at the most retarded angle. Even in a case where a vehicle includes a hybrid system in which electricity is generated by the driving force of the engine E and performs a control to stop the engine E when the battery is charged, the valve opening-closing timing control apparatus A is retained at the most retarded angle lock phase, which is an example of the retarded angle side lock phase, when the engine E is stopped. In a case of starting the engine E in a cold state after the engine E is stopped in a state where the valve opening-closing timing control apparatus A is retained at the most retarded angle lock phase, the internal combustion engine according to the embodiment shifts the relative rotational phase to the intermediate lock phase to start the engine E in a favorable condition. The detail of the case of starting the engine E in a cold state will be described later in this disclosure.

[0061] In a case where the engine E is stopped in a state where the valve opening-closing timing control apparatus A is retained at the intermediate lock phase and the engine E is started in an warm state, which is, for example, in a state immediately after the engine E is stopped in the above-mentioned state, the engine E may be started in a state as is where the valve opening-closing timing control apparatus A is retained at the intermediate lock phase, however, in the description of the control operation of the internal combustion engine according to the embodiment below, the control operation at the time of starting the engine E by changing the relative rotational phase of the valve opening-closing timing control apparatus A to the most retarded angle lock phase will be described as an example.

[0062] In the engine start control portion 61, an engine start control routine illustrated in Fig. 8 is performed when the start switch 16 is operated to ON, in other words when a start information is received, in a state where the engine E is in a stopped state. More specifically, when the engine start control portion 61 determines that the start switch 16 is operated to ON, the engine start control portion 61 obtains the temperature of the engine E that the temperature sensor 15 detects. When the detected temperature of the engine E is less than a predetermined value in step S01, the engine E is determined as in the cold state and the control routine shifts from step S01 to step S02, which is in the direction indicated as cold in the flowchart illustrated in Fig. 8. In step S02, the engine start control portion 61 obtains the information of the relative rotational phase of the valve opening-closing timing control apparatus A from a signal detected by the rotational phase sensor 14 and when the relative rotational phase is determined as at the intermediate lock phase, the control routine shifts to step S10 so as to control the starter motor 12 to start cranking, then shifts to step S11 so as to control the ignition plug 10 and the fuel injection nozzle 11 to ignite the air-fuel mixture in the combustion chamber 90 of the engine E so as to start the engine E.

[0063] In a case where the temperature of the engine E is less than the predetermine value in step S01 and the engine start control portion 61 determines that the relative rotational phase of the valve opening-closing timing control apparatus A is not at the intermediate lock phase in step S02, which is likely to be determined as at the most retarded angle lock phase in such case, the pump motor M of the second hydraulic pump P2 is driven so as to control the rotational drive portion 57 of the lift amount adjusting apparatus D and rotates the support arm 55 with the rotary axis Q as the center of rotation so as to define the position of the swing axis R at the minimum position Min. Accordingly, the lift amount of the intake valve Va is decreased to the minimum amount in step S03, which is an example of the lift amount adjustment control. In other words, in step S03, the lift amount adjusting apparatus D is controlled in a direction toward decreasing the push force of the intake valve Va that affects the rotation of the intake camshaft 7a.

[0064] Followed by step S03, in step S04, the phase control valve 41 is controlled in a state where the relative rotational phase information detected by the rotational phase sensor 14 is fed back to the engine control unit B so that the relative rotational phase is shifted in the advanced angle direction Sa toward the intermediate phase with the supply of the operation oil from the second hydraulic pump P2 and retains the relative rotational phase at the intermediate lock phase. In a case of changing the relative rotational phase toward the intermediate phase from a state in which the relative rotational phase is retained at the most retarded angle lock phase, the relative rotational phase is changed after the relative rotational phase is released from the locked state.

[0065] In step S05 followed by step S04, the rotational drive portion 57 of the lift amount adjusting apparatus D is controlled so as to control the lift amount of the intake valve Va to reach an amount corresponding to starting the engine E in the cold state. Followed by step S05, the control routine shifts to step S10 and to step S11 so as to start the engine E.

[0066] In a case where the start switch 16 is operated to ON and the temperature of the engine E is determined as equal to or more than the predetermined value in step S01, the engine E is determined as in the warm state and the control routine shifts from step S01 to step S06 by following the arrow indicated as warm in the flowchart illustrated in Fig. 8. In step S06, the engine start control portion 61 obtains the information of the relative rotational phase of the valve opening-closing timing control apparatus A from a signal detected by the rotational phase sensor 14 and when the relative rotational phase is determined as at the most retarded angle lock phase, the control routine shifts to step S10 so as to control the starter motor 12 to start cranking, then shifts to step S11 so as to control the ignition plug 10 and the fuel injection nozzle 11 to ignite the air-fuel mixture in the combustion chamber 90 of the engine E so as to start the engine E.

[0067] In a case where the temperature of the engine E is equal to or more than the predetermine value in step S01 and the engine start control portion 61 determines that the relative rotational phase of the valve opening-closing timing control apparatus A is not at the most retarded angle lock phase in step S06, which is likely to be determined as at the intermediate lock phase in such case, the pump motor M of the second hydraulic pump P2 is driven so as to control the rotational drive portion 57 of the lift amount adjusting apparatus D and rotates the support arm 55 with the rotary axis Q as the center of rotation so as to define the position of the swing axis R at the minimum position Min. Accordingly, the lift amount of the intake valve Va is decreased to the minimum amount in step S07, which is an example of the lift amount adjustment control.

[0068] Followed by step S07, in step S08, the phase control valve 41 is controlled in a state where the relative rotational phase information detected by the rotational phase sensor 14 is fed back to the engine control unit B so that the relative rotational phase is shifted in the retarded angle direction Sb toward the most retarded angle phase with the supply of the operation oil from the second hydraulic pump P2 and locks, or retains, the relative rotational phase at the most retarded angle lock phase. In a case of changing the relative rotational phase toward the most retarded angle phase from a state in which the relative rotational phase is retained at the intermediate lock phase, the relative rotational phase is changed after the relative rotational phase is released from the locked state.

[0069] In step S09 followed by step S08, the rotational drive portion 57 of the lift amount adjusting apparatus D is controlled so as to control the lift amount of the intake valve Va to reach an amount corresponding to starting the engine E in the warm state. Followed by step S09, the control routine shifts to step S10 and to step S11 so as to start the engine E.

[0070] By performing the above-described control operation of the internal combustion engine according to the embodiment and in a case where the start of the engine E is confirmed, the pump motor M of the second hydraulic pump P2 is stopped and the state of the engine E shifts to the state in which the valve unit VU is supplied with the operation oil singularly from the first hydraulic pump P1. In addition, the engine E is controlled so as to adjust the relative rotational phase of the valve opening-closing timing control apparatus A in accordance with the operation state of the engine E.

[0071] In the above-described configuration, the engine control unit B compares the current relative rotational phase with the relative rotational phase suitable for starting the engine E corresponding to the temperature of the engine E detected by the temperature sensor 15 before cranking is started. In addition, the engine control unit B determines whether or not the relative rotational phase is in a suitable phase from the information of the relative rotational phase of the valve opening-closing timing control apparatus A detected by the rotational phase sensor 14. In a case where the relative rotational phase is in the suitable phase, the engine control unit B starts the engine E by driving the starter motor 12. In a case where the relative rotational phase is not in the suitable phase, the engine control unit B controls the valve opening-closing timing control apparatus A to change the relative rotational phase of the valve opening-closing timing control apparatus A to the suitable phase before cranking is performed.

[0072] In a configuration simply supplying the operation oil to the advanced angle chamber Ca or the retarded angle chamber Cb so as to change the relative rotational phase, the cam portion 7P of the intake camshaft 7a receives a large reaction force from the intake valve Va. Accordingly, the operation oil to be supplied to the phase changing portion 81 requires high pressure, which results in increasing the amount of the operation oil. From the similar reason, in a configuration where the phase changing portion 81 of the valve opening-closing timing control apparatus A is provided with an electric motor, a large size electric motor is required to change the relative rotational phase in addition to requiring a high power electricity.

[0073] In order to resolve such disadvantages, the internal combustion engine according to this disclosure is configured to perform the lift amount adjustment control that decreases the lift amount of the intake valve Va by utilizing the lift amount adjusting apparatus D so as to change the relative rotational phase with light load and without increasing the pressure or the amount of the operation oil. In other words, the internal combustion engine according to this disclosure restrains the increase in volume and size of the first hydraulic pump P1 and the pump motor M and thus reduces the required amount of the operation oil. In a case where the internal combustion engine according to this disclosure is provided with an electric motor at the phase changing portion 81, the electric motor may be reduced in size and in power consumption required for changing the relative rotational phase.

[0074] After the relative rotational phase is changed accordingly, the support arm 55 of the lift amount adjusting apparatus D is rotated in the opposite direction so as to control the lift amount of the intake valve Va to reach an appropriate amount and by performing cranking and ignition in such state, the engine E is started in an appropriate condition.

[0075] The internal combustion engine according to alternative embodiments will be described next. The configurations of the internal combustion engine according to the embodiment may be altered in following manners.

[0076] In the internal combustion engine according to the embodiment, the second assist portion 72 includes the second hydraulic pump P2, which is driven by the pump motor M, however, alternatively, the second assist portion 72 may be configured with an accumulator 72a as Fig. 9 illustrates, the accumulator 72a similar to the accumulator disclosed in Reference 3. The accumulator 72a is configured to accumulate the operation oil from a hydraulic pump driven by the engine E in a pressurized state and supplies the operation oil in the pressurized state, for example, to the phase changing portion 81 and the lift amount adjusting portion (the rotational drive portion 57). By the second assist portion 72 configured with the accumulator 72a, the pump motor M may be omitted for simplifying the configuration.

[0077] Alternatively, the lift amount adjusting apparatus D may be provided with the lift amount adjusting portion (the rotational drive portion 57) that operates by supplying the operation oil. In such case, the lift amount adjusting apparatus D is operated by the operation oil supplied from the second hydraulic pump P2. Accordingly, the second assist portion 72 configured with the second hydraulic pump P2, the pump motor M, and the power source PS supplying power to the pump motor M may serve to adjust the lift amount even in a state where the engine E is stopped.

[0078] Alternatively, the phase changing portion 81 of the valve opening-closing timing control apparatus A may be configured to change the relative rotational phase driven by an electric motor. In such case, the power source PS that supplies power to the phase changing portion 81 may serve as the power source PS for operating the first assist portion 71 that adjusts the lift amount of the intake valve Va even in a state where the engine E is stopped.

[0079] The internal combustion engine according to this disclosure may be applied to an engine including a valve opening-closing timing control apparatus controlling the opening-closing timing of the valves and a lift amount adjusting apparatus that defines the lift amount of the valves.

Claims

1. An internal combustion engine (E), comprising:

    a lift amount adjusting apparatus (D) driven by a lift amount adjusting portion (57) and adjusting a lift amount of a valve (Va, Vb) at a combustion chamber (90) when a camshaft (7a, 7b) for opening and closing the valve (Va, Vb) of the internal combustion engine (E) rotates;

    a valve opening-closing timing control apparatus (A) including a driving-side rotating member (20) synchronously rotating with a crankshaft (1) of the internal combustion engine (E), a driven-side rotating member (30) coaxially positioned relative to the driving-side rotating member (20) and integrally rotating with the camshaft (7a, 7b), and a lock mechanism (L) retaining a relative rotational phase between the driving-side rotating member (20) and the driven-side rotating member (30) at a predetermined lock phase, the valve opening-closing timing control apparatus (A) driven by a phase changing portion (81) and adjusting opening-closing timings of the valve (Va, Vb) by selectively changing the relative rotational phase between the driving-side rotating member (20) and the driven-side rotating member (30) toward an advanced angle direction (Sa) or toward a retarded angle direction (Sb) that is different from the advanced angle direction (Sa);

    a first assist portion (71) configured to adjust the

lift amount adjusted by the lift amount adjusting portion (57) while the internal combustion engine (E) is in a stopped state;
a second assist portion (72) configured to change the relative rotational phase changed by the phase changing portion (81) while the internal combustion engine (E) is in the stopped state; and
an engine control portion (B) performing a lift amount adjustment control controlling the lift amount adjusting portion (57) to reduce a push force that the valve (Va, Vb) applies on the camshaft (7a, 7b) when the camshaft (7a, 7b) rotates in a case where the engine control portion (B) receives start information of the internal combustion engine (E), controlling the phase changing portion (81) then to change the relative rotational phase toward the advanced angle direction (Sa) or toward the retarded angle direction (Sb) on a basis of a predetermined condition, controlling the lift amount adjusting portion (57) then to make the lift amount reach a predetermined amount corresponding to the predetermined condition, and driving a starter motor (12) of the internal combustion engine (E) after the engine control portion (B) controls the lift amount adjusting portion (57) to make the lift amount reach the predetermined amount corresponding to the predetermined condition.

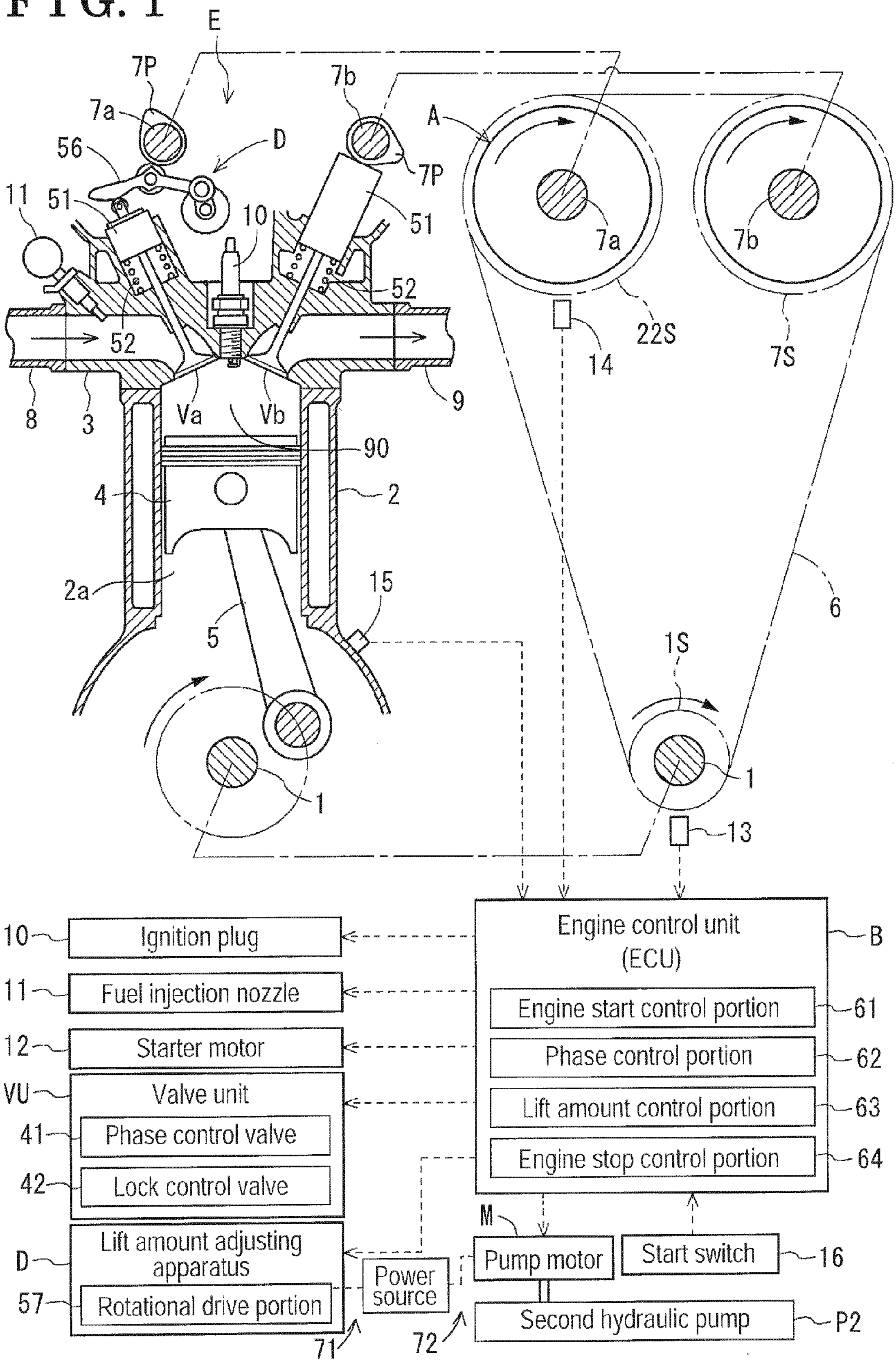
2. The internal combustion engine (E) according to Claim 1, further comprising:

a temperature sensor (15) detecting temperature of the internal combustion engine (E); and
a rotational phase sensor (14) detecting the relative rotational phase of the valve opening-closing timing control apparatus (A), wherein
the predetermined condition is temperature of the internal combustion engine (E), wherein
the lock mechanism (L) is configured to retain the relative rotational phase between the driving-side rotating member (20) and the driven-side rotating member (30) at minimum of two different lock phases including an intermediate lock phase and a retarded angle side lock phase that is different from the intermediate lock phase, the intermediate lock phase being suitable for starting the internal combustion engine (E) when the temperature of the internal combustion engine (E) is equal to or lower than a predetermined temperature and the retarded angle side lock phase being suitable for starting the internal combustion engine (E) when the temperature of the internal combustion engine (E) is higher than the predetermined temperature, wherein
the engine control portion (B) controls the phase changing portion (81) to define the relative rotational phase on the basis of detected results from the temperature sensor (15) and the rotational phase sensor (14), controls the phase changing portion (81) to change the relative rotational phase to be at the retarded angle side lock phase when the engine control portion (B) determines that the temperature of the internal combustion engine (E) is higher than the predetermined temperature and determines that the relative rotational phase is at the intermediate lock phase, and controls the phase changing portion (81) to change the relative rotational phase to be at the intermediate lock phase when the engine control portion (B) determines that the temperature of the internal combustion engine (E) is equal to or lower than the predetermined temperature and determines that the relative rotational phase is at the retarded angle side lock phase.

3. The internal combustion engine (E) according to Claim 1 or 2, wherein
the driven-side rotating member (30) is internally accommodated by the driving-side rotating member (20) to provide a fluid pressure chamber (C) partitioned into an advanced angle chamber (Ca) and a retarded angle chamber (Cb) at a position between the driven-side rotating member (30) and the driving-side rotating member (20), wherein
the phase changing portion (81) changes the relative rotational phase toward the advanced angle direction (Sa) by supplying a fluid to the advanced angle chamber (Ca) and changes the relative rotational phase toward the retarded angle direction (Sb) different from the advanced angle direction (Sa) by supplying the fluid to the retarded angle chamber (Cb), wherein
the second assist portion (72) is configured with an accumulator (72a) accumulating the fluid in a pressurized state or with an electric fluid pressure pump (P2) discharging the fluid by electric power.

4. The internal combustion engine (E) according to Claim 2, wherein the retarded angle side lock phase is defined at a phase at most retarded angle and phases close to the most retarded angle.

FIG. 1


E
7P
7a
7b
A
D
56
7P
11
51
10
51
7a
7b
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52
22S
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14
8
3
Va
Vb
9
90
4
2
2a
15
6
5
1S
1
1
13
10
Ignition plug
Engine control unit
(ECU)
B
11
Fuel injection nozzle
Engine start control portion
61
12
Starter motor
Phase control portion
62
VU
Valve unit
Lift amount control portion
63
41
Phase control valve
42
Lock control valve
Engine stop control portion
64
M
D
Lift amount adjusting apparatus
Pump motor
Start switch
16
Power source
57
Rotational drive portion
Second hydraulic pump
P2
71
72

FIG. 2

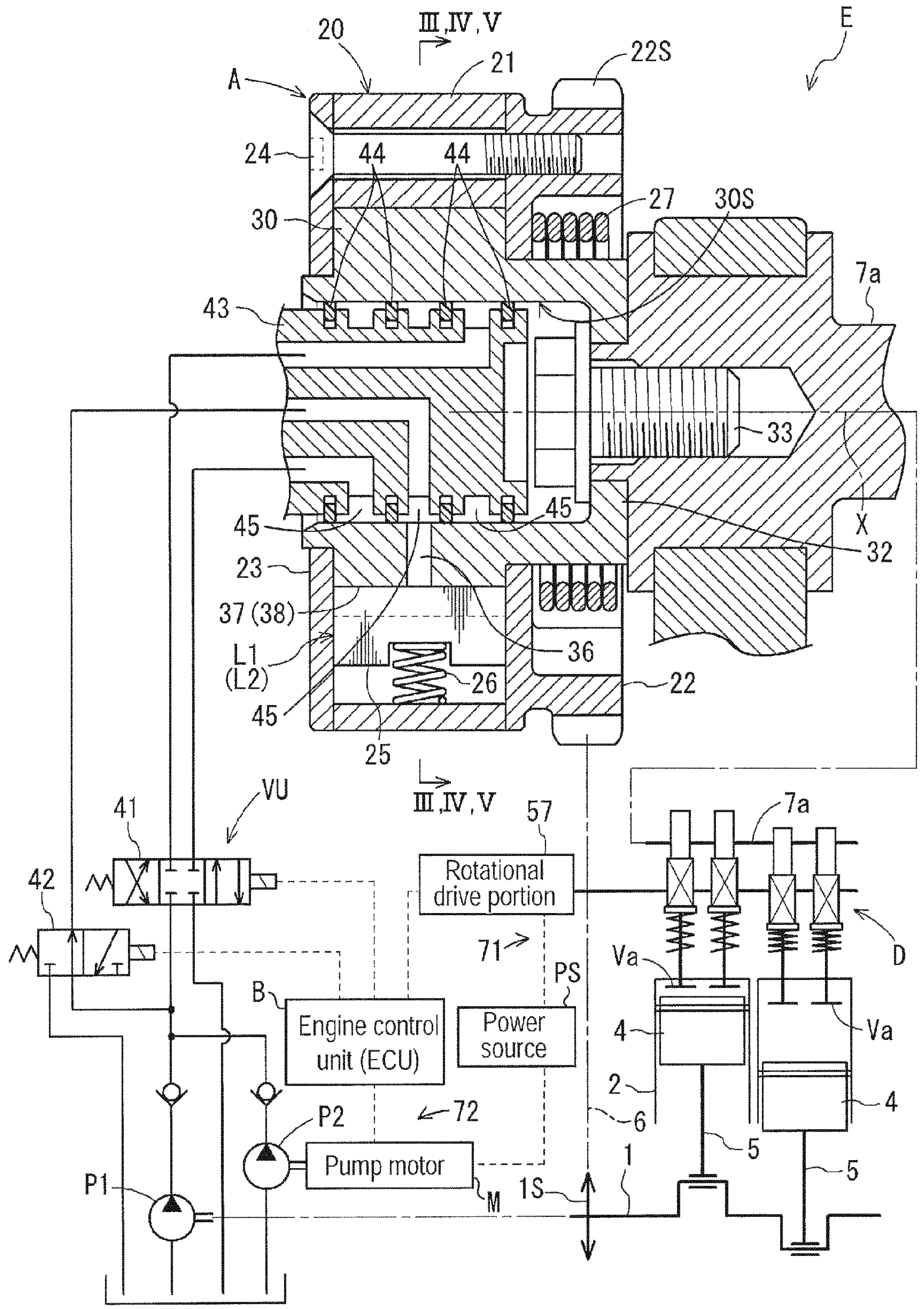
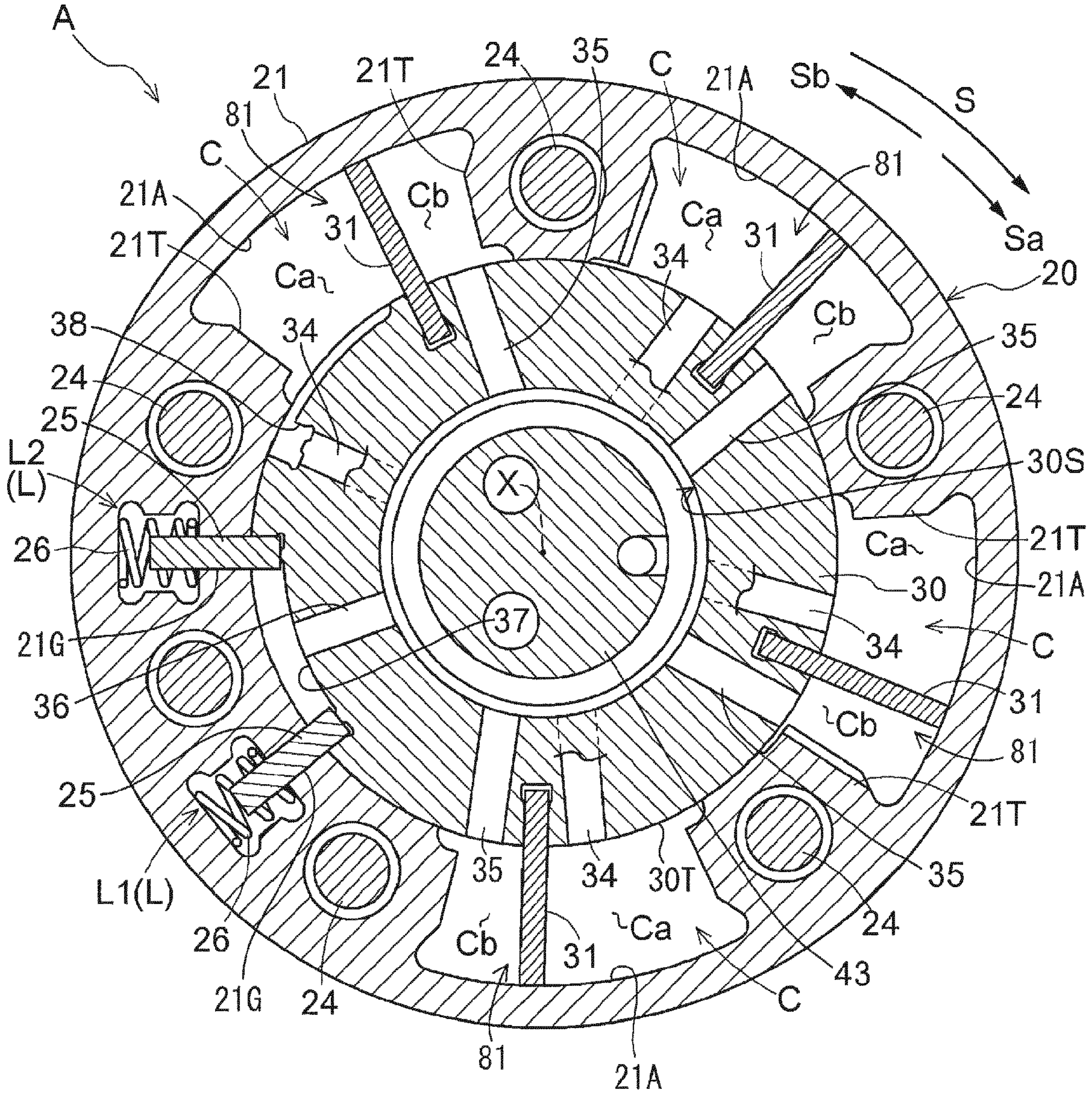

III, IV, V
20
21
22S
E
A
24
44
44
27
30S
30
7a
43
33
X
45
45
32
23
37 (38)
36
L1
(L2)
26
22
45
25
III, IV, V
41
VU
57
7a
42
Rotational drive portion
71
D
Va
PS
B
Engine control unit (ECU)
Power source
4
Va
2
4
72
6
P2
5
Pump motor
5
P1
1S
1
M

FIG. 3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35
C
21A
Sb
S
Sa
81
C
21A
21T
Cb
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Ca
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81
20
Cb
35
38
34
24
25
24
L2
(L)
30S
26
X
21T
Ca
21A
30
21G
37
34
C
36
31
Cb
81
25
21T
35
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30T
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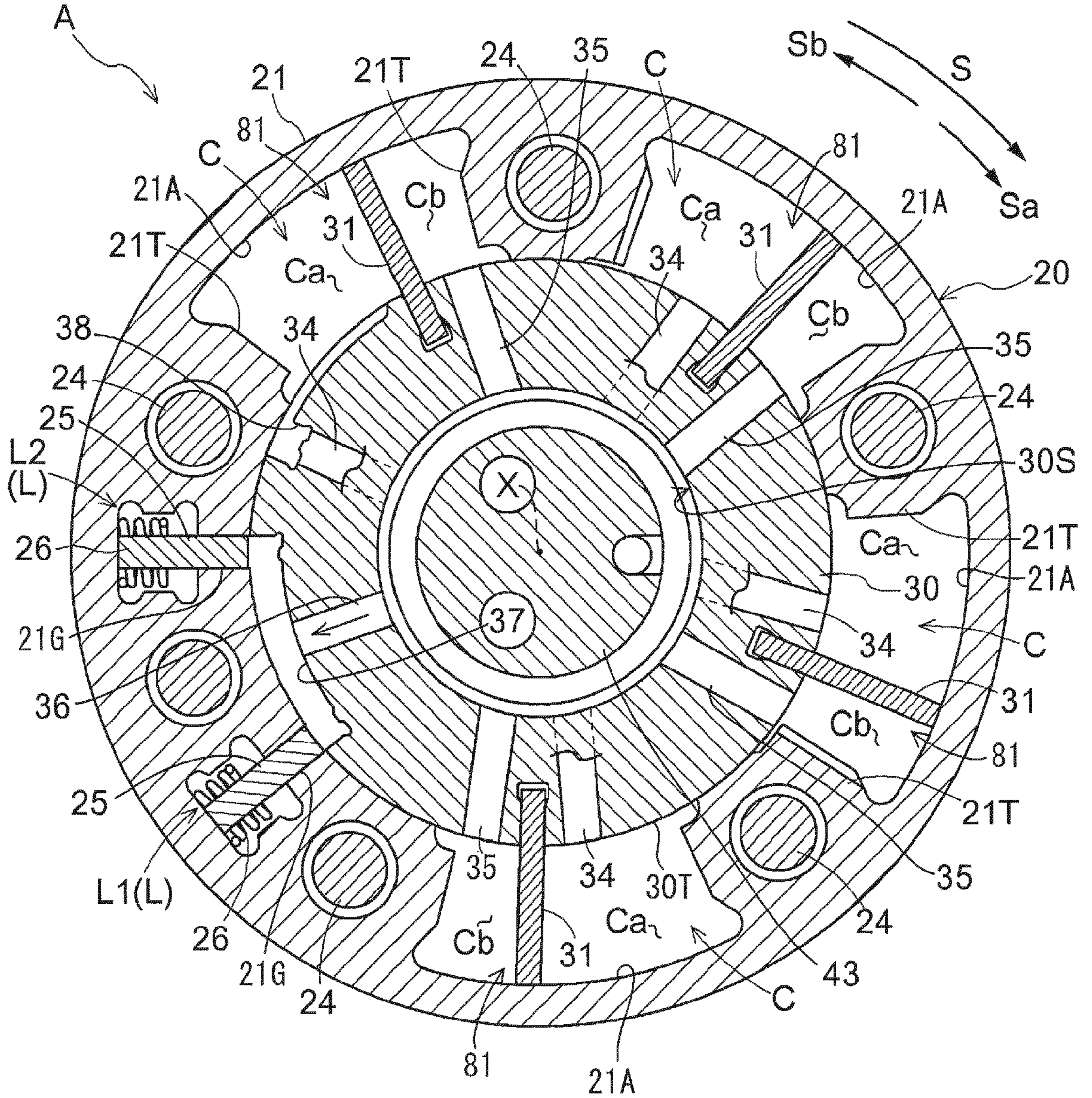
Ca
24
26
31
43
21G
24
C
81
21A

F I G. 4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Cb
35
38
24
25
L2
(L)
26
21G
36
25
L1(L)
26
21G
24
35
34
30T
Ca
Cb
31
81
21A
C
43
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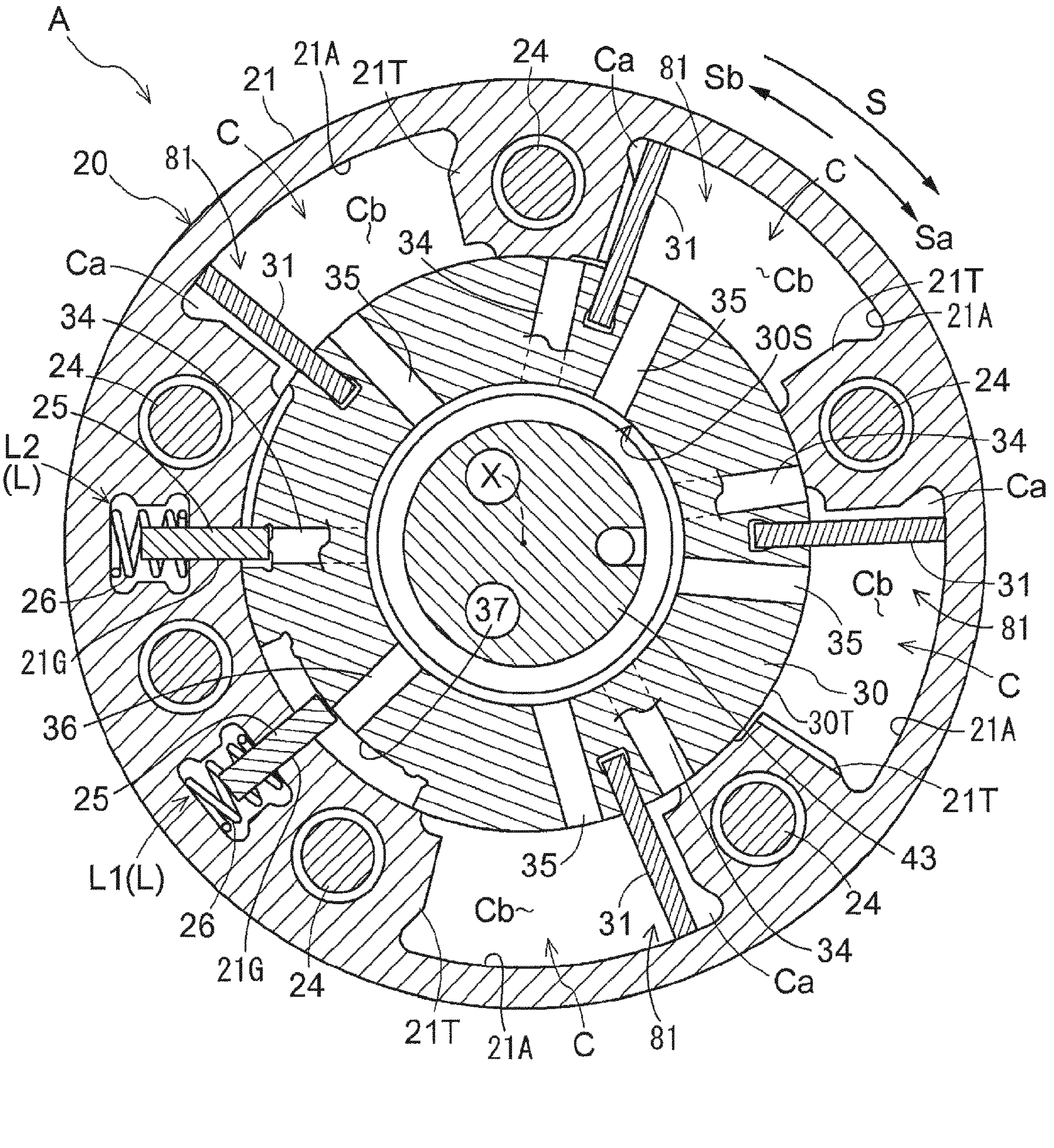
21T
81
31
C
34
30
21A
21T
30S
24
X
37

FIG. 5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34
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36
37
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Sb
X
L1(L)
L2
(L)

F I G. 6

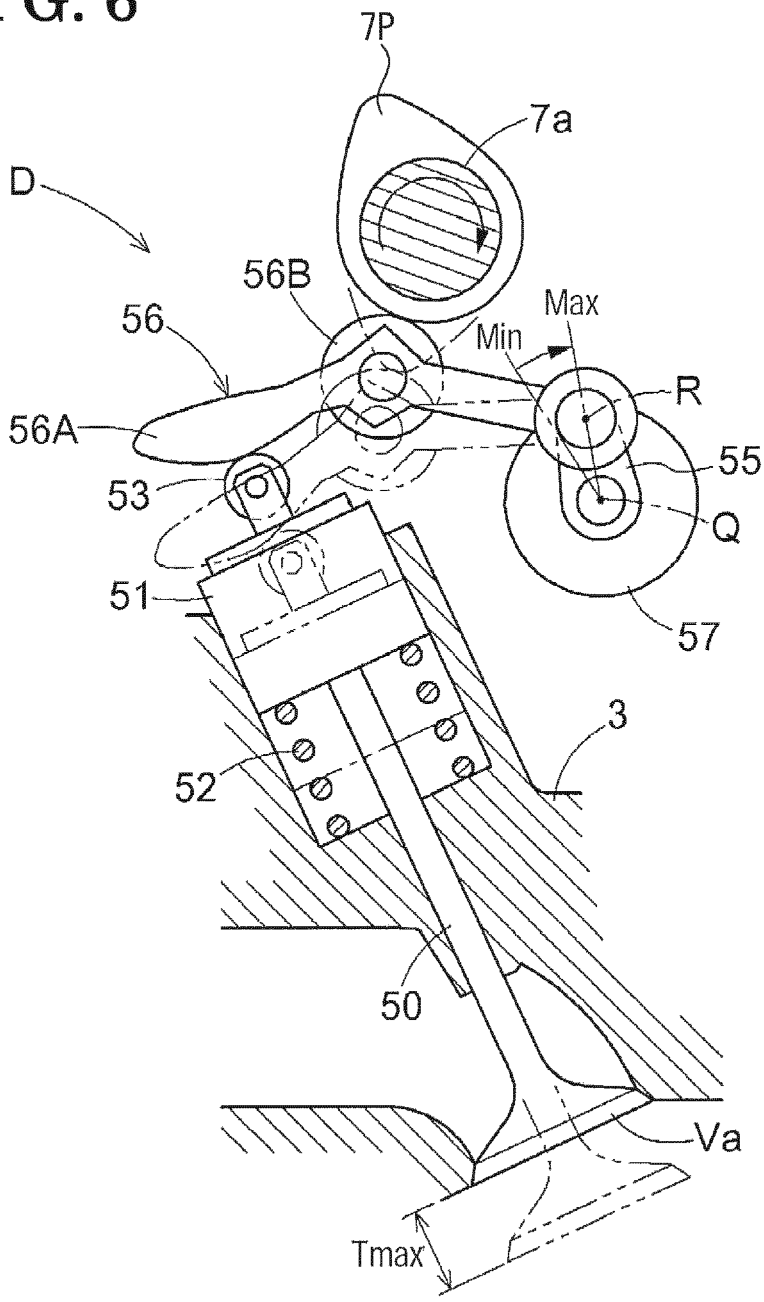
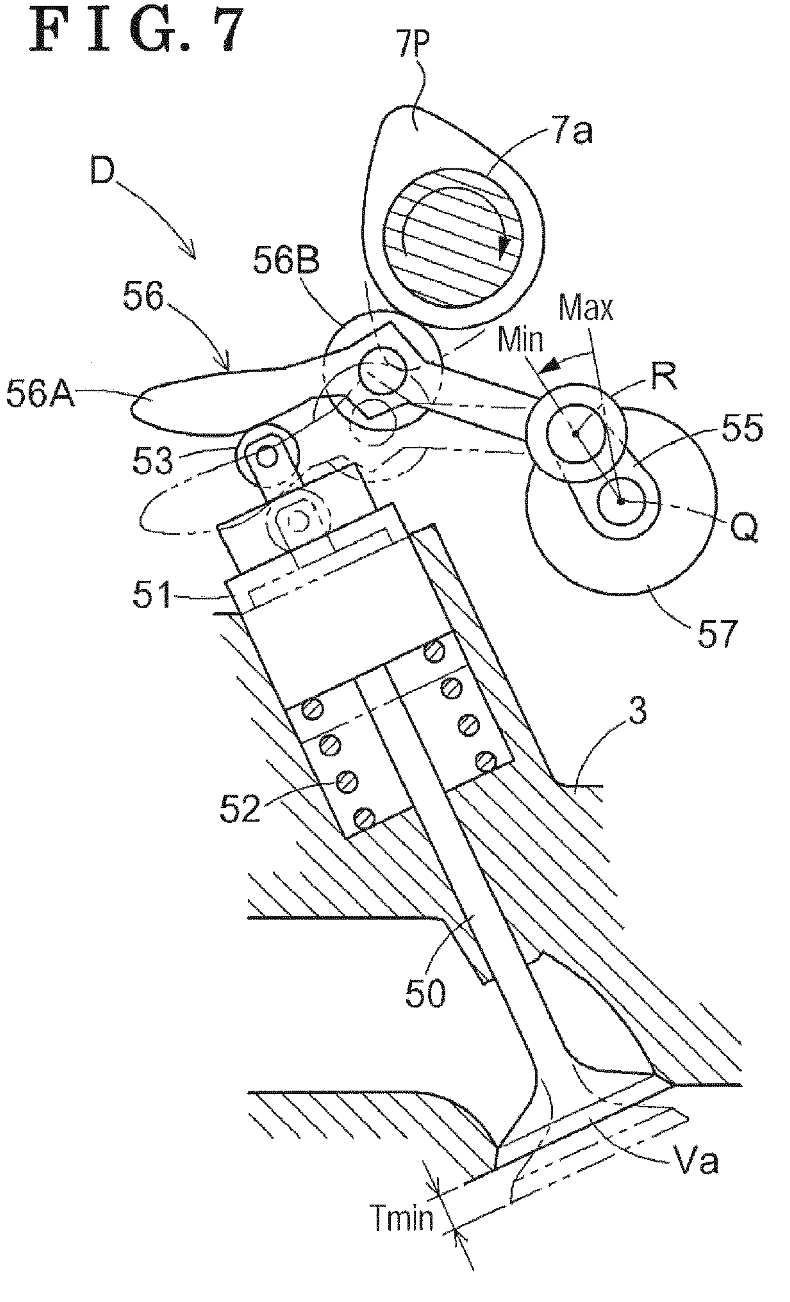


FIG. 7



F I G. 8

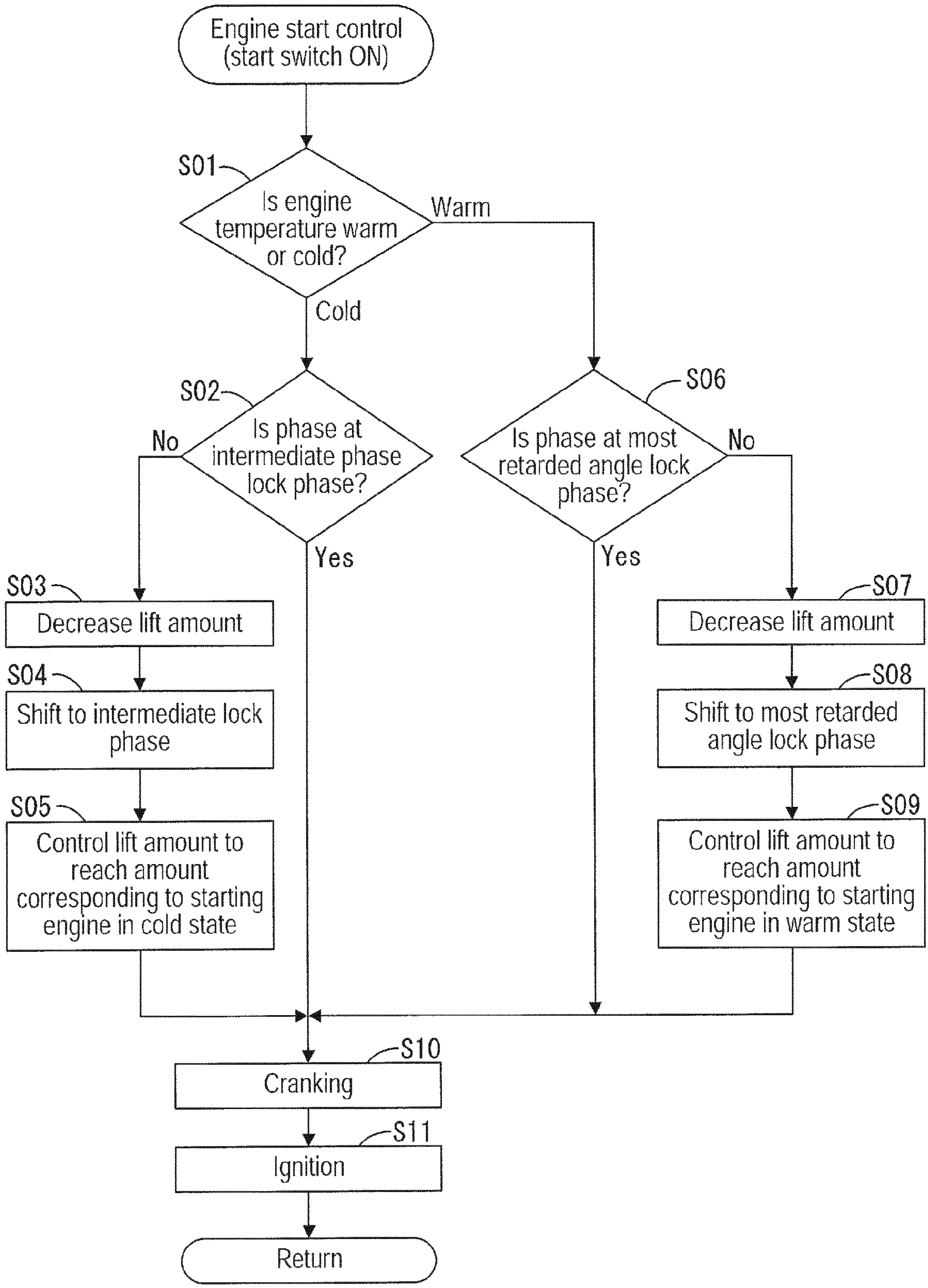
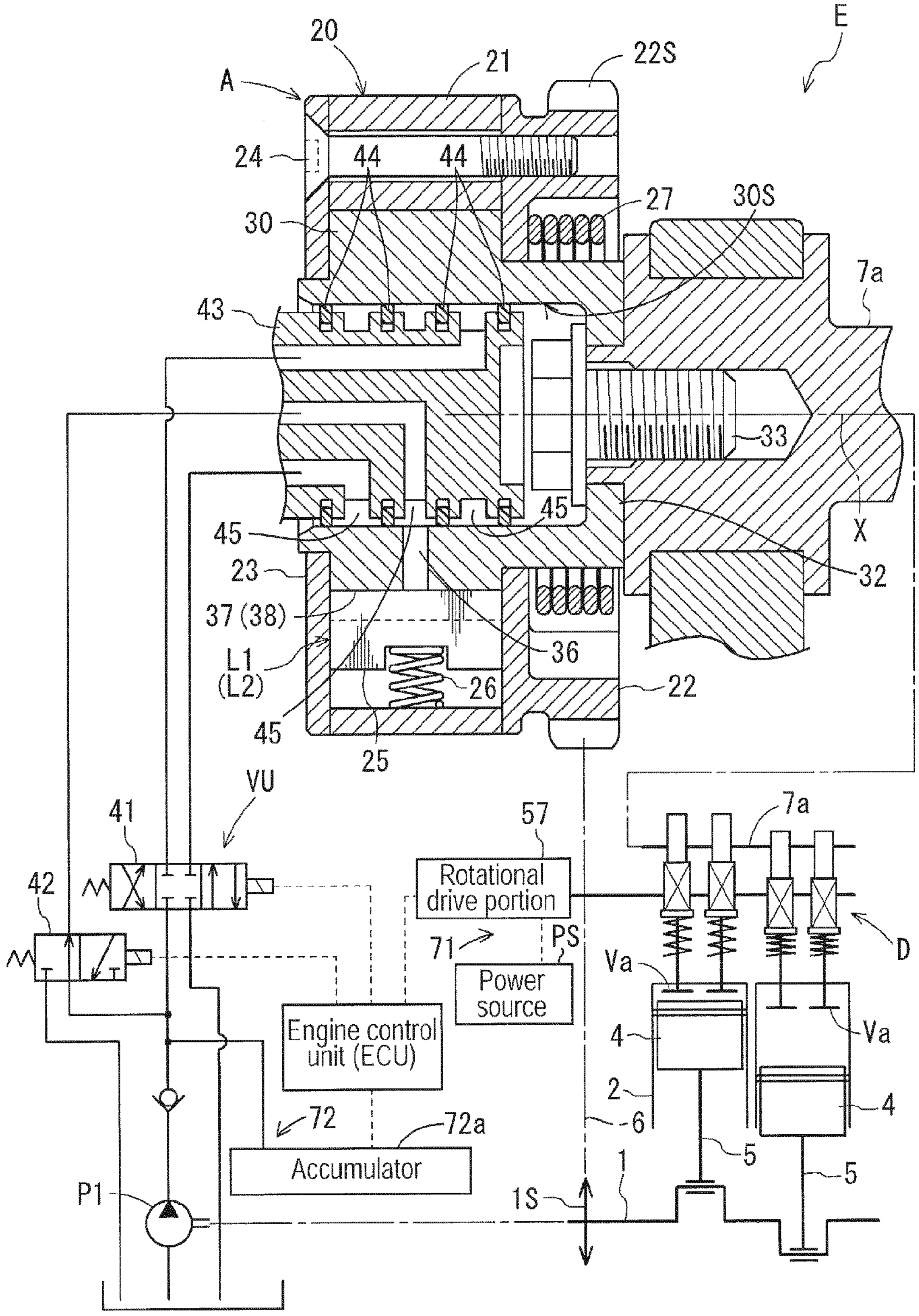

Engine start control
(start switch ON)
S01
Is engine temperature warm or cold?
Warm
Cold
S02
Is phase at intermediate phase lock phase?
No
Yes
S06
Is phase at most retarded angle lock phase?
No
Yes
S03
Decrease lift amount
S04
Shift to intermediate lock phase
S05
Control lift amount to reach amount corresponding to starting engine in cold state
S07
Decrease lift amount
S08
Shift to most retarded angle lock phase
S09
Control lift amount to reach amount corresponding to starting engine in warm state
S10
Cranking
S11
Ignition
Return

FIG. 9


20
21
22S
E
A
24
44
44
30
27
30S
7a
43
33
X
45
45
32
23
37 (38)
36
L1
(L2)
26
22
45
25
VU
41
57
7a
42
Rotational drive portion
71
PS
D
Va
Power source
Va
Engine control unit (ECU)
4
2
4
72
72a
6
5
Accumulator
1
5
P1
1S

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EUROPEAN SEARCH REPORT

Application Number
EP 14 16 0859

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F01L

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	17 June 2014	Klinger, Thierry

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