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## (54) Valve timing control apparatus for internal combustion engine

(57) A valve timing control apparatus includes a driving side rotational member (2) synchronously rotated with a crankshaft, a driven side rotational member (1) provided coaxially with the driving side rotational member and synchronously rotated with a camshaft (3), a fluid pressure chamber (40) being separated into an advanced angle chamber (43) and a retarded angle chamber (42), a phase control apparatus (9, 71, 76)-controlling an operation fluid to be supplied to and discharged from one of, or both of the advanced angle chamber and the retarded angle chamber, for displacing a relative rotational phase between the driving side rotational member and the driven side rotational member within a range from a most advanced angle phase to a most retarded angle phase, a locking mechanism (6) restraining the relative rotational phase at a lock phase between the most advanced angle phase and the most retarded angle phase.

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## Description

FIELD OF THE INVENTION

**[0001]** This invention relates to a valve timing control apparatus for controlling an opening and closing timing of valves of an internal combustion engine for a vehicle engine, or the like.

BACKGROUND

**[0002]** A valve timing control apparatus is known which appropriately adjusts an opening and closing timing of a valve, and achieves optimal driving conditions by means of a displacement of a relative rotational phase between a driving side rotational member, which rotates in synchronization with a crankshaft, and a driven side rotational member, which rotates in synchronization with a camshaft. A known valve timing control apparatus is disclosed in JP2002-097912A (see pp.2-3 Figs. 2-5).

**[0003]** The disclosed valve timing control apparatus includes a housing member synchronously rotatable with the crankshaft, a rotor member synchronously rotatable with the camshaft, a relative rotation controlling mechanism actuated in response to supply and discharge of operation fluid, a fluid pressure circuit for controlling the operation fluid to be supplied to and discharged from an advanced angle fluid chamber, a retarded angle fluid chamber, and the relative rotation controlling mechanism, and an auxiliary controlling mechanism actuated in response to the operation fluid supplied to and discharged from the fluid pressure circuit. The rotor is relatively rotatably assembled on a shoe portion provided at the housing member and forms the advanced angle fluid chamber and the retarded angle fluid chamber at a vane portion in the housing member. The relative rotation controlling mechanism allows a relative rotation of the housing member and the rotor member under an unlock state, and restricts the relative rotation of the housing member and the rotor member at a lock phase between a most advanced angle phase and a most retarded angle phase under a lock state. The auxiliary controlling mechanism allows the relative rotation of the housing member and the rotor member under the unlock state, and restricts the relative rotation of the rotor member only to the retarded angle side (or to the advanced angle side) relative to the housing member at a set phase between the most retarded angle phase (or the most advanced angle phase) and the lock phase under the lock state.

**[0004]** According to this known valve timing control apparatus, when the relative rotational phase between the housing member and the rotor member is displaced from the most retarded angle phase (or the most advanced angle phase) to the set phase by means of a torque fluctuation applied to the camshaft, the auxiliary controlling mechanism comes into the lock state. Then, the auxiliary controlling mechanism restricts the relative rotation of the rotor member only to the retarded angle side (or to the advanced angle side) relative to the housing member, and an initial value of the relative rotational phase is held at the set phase. Accordingly, thereafter, the relative rotational phase between the housing member and the rotor member is displaced to the lock phase by means of the torque fluctuation applied to the camshaft, and the relative rotation of the housing member and the rotor member is restricted at the lock phase by means of the relative rotation controlling mechanism. Thereby, the time required for the relative rotation of the housing member and the rotor member to be restricted at the lock phase from the point of the internal combustion engine starting by means of the relative rotation controlling mechanism can be reduced. Further, an occurrence of a hitting sound and difficulties associated with a startability of the internal combustion engine can be reduced.

**[0005]** The valve timing control apparatus disclosed in JP2002-097912A, oscillates the relative rotational phase to displace its posture to the set phase by means of the torque fluctuation applied to the camshaft, and then makes the auxiliary controlling mechanism into the lock state. Therefore, depending on, for example, conditions of the operation fluid in the valve timing control apparatus, or types of the operation fluid at the time of the displacement of the relative rotational phase, a sufficient oscillation of the relative rotational phase cannot be ensured because of a resistance of the operation fluid, and the valve timing control apparatus may occasionally fail to displace the relative rotational phase to the set phase. For example, shortly after a stop of the internal combustion engine, when the advanced angle fluid chamber, the retarded angle fluid chamber, and the fluid pressure circuit communicating therewith are filled with the operation fluid, or when a temperature of the operation fluid is at a lower degree, the resistance of the operation fluid at the time of the oscillation of the relative rotational phase is increased. On this occasion, the valve timing control apparatus may occasionally fail to displace the relative rotational phase to the set phase. In such a case, the relative rotation controlling mechanism might fail to restrain the relative rotational phase at the lock phase, and a startability of the internal combustion engine may occasionally be adversely affected.

**[0006]** A need thus exists for a valve timing control apparatus, which, notwithstanding the conditions of the operation fluid in the valve timing control apparatus, or types of the operation fluid, certainly restrains the relative rotational phase between the driving side rotational member and the driven side rotational member at the lock phase, and improves the startability of the internal combustion engine.

## SUMMARY OF THE INVENTION

**[0007]** According to an aspect of the present invention, a valve timing control apparatus includes a driving side rotational member synchronously rotated with a crankshaft, a driven side rotational member provided coaxially

with the driving side rotational member and synchronously rotated with a camshaft, a fluid pressure chamber formed on at least one of the driving side rotational member and the driven side rotational member, the fluid pressure chamber being separated into an advanced angle chamber and a retarded angle chamber, a phase control apparatus controlling an operation fluid to be supplied to and discharged from one of, or both of the advanced angle chamber and the retarded angle chamber, for displacing a relative rotational phase between the driving side rotational member and the driven side rotational member within a range from a most advanced angle phase to a most retarded angle phase, a locking mechanism restraining the relative rotational phase between the driving side rotational member and the driven side rotational member at a lock phase between the most advanced angle phase and the most retarded angle phase. During cranking, the relative rotational phase is displaced relatively in one of an advanced angle direction and a retarded angle direction while oscillating. The phase control apparatus performs a starting point control for draining the operation fluid from the advanced angle chamber and the retarded angle chamber during a predetermined period of time after a starting of cranking, and supplying the operation fluid into one of the advanced angle chamber and the retarded angle chamber for displacing the relative rotational phase to the other of the advanced angle direction and the retarded angle direction after the predetermined period of time is elapsed.

**[0008]** According to the embodiment of the present invention, during the predetermined period of time after the staring of cranking, the cranking is performed in a condition where the operation fluid in both of the advanced angle chamber and the retarded angle chamber is drained. Therefore, by means of the oscillation of the relative rotational phase, the relative rotational phase can be displaced in one of the advanced angle direction and the retarded angle direction while draining the operation fluid from the advanced angle chamber and the retarded angle chamber. Accordingly, in a condition where the lock phase is positioned at one of the advanced angle side and the retarded angle side relative to the relative rotational phase at the starting of cranking, the relative rotational phase can be restrained by means of the locking mechanism. In contrast, in a condition where the lock phase is not positioned at the one of the advanced angle side and the retarded angle side, the operational fluid is supplied into one of the advanced angle chamber and the retarded angle chamber for displacing the relative rotational phase to the other of the advanced angle side and the retarded angle side after the predetermined period of time is elapsed, thus the relative rotational phase can be restrained by means of the locking mechanism. Accordingly, the reliability of the restraint of the relative rotational phase by means of the locking mechanism at the starting of the internal combustion engine can be improved.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** The foregoing and additional features and characteristics of the present invention will become more apparent from the following detailed description considered with reference to the accompanying drawings, wherein:

**[0010]** Fig. 1 is a sectional view of a valve timing control apparatus according to an embodiment of the present invention.

**[0011]** Fig. 2 is a sectional view of the valve timing control apparatus illustrating a condition where a relative rotational phase is at a lock phase and a locking mechanism is at a lock state, the sectional view which is taken along line II-II of Fig. 1.

**[0012]** Fig. 3 is a sectional view of the valve timing control apparatus illustrating a condition where the relative rotational phase is at the lock phase and the locking mechanism is at an unlock state of the sectional view which is taken along line III-III of Fig. 1.

**[0013]** Fig. 4 is a sectional view of the valve timing control apparatus illustrating a condition where the relative rotational phase is at a restriction phase, the sectional view which is taken along line IV-IV of Fig. 1.

**[0014]** Fig. 5 is a sectional view of the valve timing control apparatus illustrating a condition where the relative rotational phase is at a most retarded angle phase, the sectional view which is taken along line V-V of Fig. 1.

**[0015]** Fig. 6 is a sectional view of the valve timing control apparatus illustrating a condition where the relative rotational phase is at a most advanced angle phase, the sectional view which is taken along line VI-VI of Fig. 1.

**[0016]** Fig. 7 is a view for explaining a relation between a stroke degree of a spool and operating conditions of a control valve according to the embodiment of the present invention.

**[0017]** Fig. 8 is a block diagram illustrating an electrical connection structure of a control unit according to the embodiment of the present invention.

**[0018]** Fig. 9 is a flowchart illustrating an operation control of the valve timing control apparatus at a starting of an engine.

**[0019]** Fig. 10 is a timing chart illustrating an operation of the valve timing control apparatus in a condition where the relative rotational phase at a starting of cranking is at the most advanced angle phase.

**[0020]** Fig. 11 is a timing chart illustrating an operation of the valve timing control apparatus in a condition where the relative rotational phase at the starting of cranking is at the most retarded angle phase.

## DETAILED DESCRIPTION

**[0021]** An embodiment of the present invention will be explained hereinbelow with reference to the attached drawings.

**[0022]** As illustrated in Figs. 1-3, a valve timing control apparatus according to the embodiment of the present invention includes an outer rotor 2 (i.e., a driving side

rotational member), and an inner rotor 1 (i.e., a driven side rotational member). The outer rotor 2 rotates in synchronization with a crankshaft of an engine (not shown), and the inner rotor 1 is coaxially provided with the outer rotor 2 and rotates in synchronization with a camshaft 3.

**[0023]** The inner rotor 1 is integrally assembled at an end portion of the camshaft 3, which configures a rotational shaft of a cam for controlling an opening and closing timing of an intake valve and an exhaust valve of the engine. The camshaft 3 is rotatably assembled to a cylinder head of the engine.

**[0024]** Relative to the inner rotor 1, the outer rotor 2 is externally attached, and relatively rotatable within a predetermined relative rotational phase range. The outer rotor 2 is integrally provided with, at a side in which the camshaft 3 is connected, a rear plate 23, and is integrally provided with, at the other side, a front plate 22. Further, the outer rotor 2 is integrally provided with, at an outer circumference, a timing sprocket 20. A transmission member 24 such as a timing chain, a timing belt, or the like, is hung across the timing sprocket 20 and a sprocket assembled to the crankshaft of the engine.

**[0025]** When the crankshaft of the engine is rotated, a rotational force is transmitted to the timing sprocket 20 through the transmission member 24, then the outer rotor 2 rotates in a rotational direction S as illustrated in Fig. 2. Consequently, the inner rotor 1 rotates in the rotational direction S, then the camshaft 3 rotates, and then the cam provided at the camshaft 3 pushes down the intake valve or the exhaust valve of the engine to open the valve.

**[0026]** As illustrated in Fig. 2, the outer rotor 2 is arranged with plural protruding portions 4 along a rotational direction in such a manner to separate from each other. Each protruding portion 4 (i.e., a shoe) is protruded in a radial direction. Between each adjacent protruding portion 4 of the outer rotor 2, a fluid pressure chamber 40, defined by the outer rotor 2 and the inner rotor 1, is provided. According to the embodiment of the present invention, four fluid pressure chambers 40 are provided.

**[0027]** The inner rotor 1 is formed with, at a part of an outer circumferential portion facing the fluid pressure chamber 40, a vane groove 41. A vane 5, which separates the fluid pressure chamber 40 into an advanced angle chamber 43 and a retarded angle chamber 42 in a relative rotational direction (a direction of arrows S1 and S2 in Fig. 2), is slidably inserted into the vane groove 41 in a radial direction. As illustrated in Fig. 1, the vane 5 is biased toward an inner wall surface w of the fluid pressure chamber 40 by means of a spring 51 provided at a side of an inner diameter of the vane 5.

**[0028]** The advanced angle chamber 43 of the fluid pressure chamber 40 is communicated with an advanced angle passage 11 formed in the inner rotor 1, the retarded angle chamber 42 is communicated with a retarded angle passage 10 formed in the inner rotor 1, and the both of the advanced and retarded angle passages 11 and 10 are connected to a fluid pressure circuit 7. By supplying or discharging the operation fluid through the fluid pressure circuit 7 relative to one of, or both of the advanced angle chamber 43 and the retarded angle chamber 42, a biasing force is generated. The biasing force displaces a relative rotational phase between the inner rotor 1 and the outer rotor 2 within a range from a most advanced angle phase to a most retarded angle phase, or holds the relative rotational phase between the inner rotor 1 and the outer rotor 2 at a given phase.

**[0029]** As illustrated in Fig. 1, between the inner rotor 1 and the front plate 22 of the outer rotor 2, a torsion spring 27 serving as a biasing mechanism is provided that biases the relative rotational phase between the inner rotor 1 and the outer rotor 2 in the advanced angle direction. More particularly, the torsion spring 27 applies a torque, which normally biases the inner rotor 1 and the outer rotor 2, in a direction in which the vane 5 is displaced in the advanced angle direction (a direction of S2 in Fig. 2). A torque setting of the torsion spring 27 is set so as to displace the relative rotational phase between the outer rotor 2 and the inner rotor 1 (hereinafter, the relative rotational phase) relatively in the retarded angle direction while oscillating during cranking for starting the engine. More particularly, according to the embodiment of the present invention, a torque fluctuation applied to the camshaft 3 during cranking is large in the retarded angle direction, and is small in the advanced angle direction. Therefore, by means of the torque fluctuation, the relative rotational phase is displaced relatively in the retarded angle direction while oscillating. The torque setting of the torsion spring 27 is set for biasing the relative rotational phase in the advanced angle direction within a range in which the displacement of the relative rotation in the retarded angle direction is not interrupted. The torque fluctuation, which is applied to the camshaft 3 during cranking, is generated by means of, for example, a resistance of a valve spring in a condition where the cam provided at the camshaft 3 performs an opening and closing operation of the engine valve against the biasing force of the valve spring.

**[0030]** Further, between the inner rotor 1 and the outer rotor 2, the locking mechanism 6 is provided that is capable of restraining the relative rotation of the inner rotor 1 and the outer rotor 2 in a condition where the relative rotational phase is at a predetermined lock phase (a phase illustrated in Fig. 2) between the most advanced angle phase and the most retarded angle phase. The locking mechanism 6 includes a retarded angle locking portion 6A and an advanced angle locking portion 6B both of which are provided at the outer rotor 2. The locking mechanism 6 further includes a recess formed locking chamber 62 provided at a part of the outer circumference portion of the inner rotor 1. The locking chamber 62 communicates with a locking passage 63 formed in the inner rotor 1, and the locking passage 63 is connected to the fluid pressure circuit 7.

**[0031]** Each retarded angle locking portion 6A and the advanced angle locking portion 6B includes a locking member 60, which is provided at the outer rotor 2 and

slidable in the radial direction, and a spring 61, which biases the locking member 60 inwardly in the radial direction. According to various usages, the locking member 60 may adopt various shapes such as a plate shape, and a pin shape.

**[0032]** The retarded angle locking portion 6A prevents the inner rotor 1 from relatively rotating in the retarded angle direction relative to the outer rotor 2 by protruding the locking member 60 into the locking chamber 62. In contrast, the advanced angle locking portion 6B prevents the inner rotor 1 from relatively rotating in the advanced angle direction relative to the outer rotor 2 by protruding the locking member 60 into the locking chamber 62. More particularly, by protruding one of the retarded angle locking portion 6A and the advanced angle locking portion 6B into the locking chamber 62, a displacement of the relative rotational phase into one of the retarded angle direction and the advanced angle direction is restricted, and the displacement of the relative rotational phase into the other of the retarded angle direction and the advanced angle direction is allowed. On this occasion, a protruding operation of the locking member 60 into the locking chamber 62 is performed, by means of a biasing force of the spring 61, in a drain condition where the operation fluid is not supplied into the locking chamber 62.

**[0033]** According to the embodiment of the present invention, the locking chamber 62 is provided with, at a retarded angle side, a restricting step portion 64. The restricting step portion 64 is formed stepwise on an outer circumferential surface of the inner rotor 1. The restricting step portion 64 is provided at a wall portion extending in the radial direction at the retarded angle side of the locking chamber 62 into which the retarded angle locking portion 6A is insertable. According to the embodiment of the present invention, a restriction phase is defined between the most retarded angle phase (a phase illustrated in Fig. 5) and the lock phase (phases illustrated in Figs. 2-3). When the retarded angle locking portion 6A of the locking mechanism 6 is protruded and engaged with the restricting step portion 64 as illustrated in Fig. 4, the restricting step portion 64 restricts the displacement of the relative rotational phase to the retarded angle side from the restriction phase, and allows the displacement of the relative rotational phase to the advanced angle side.

**[0034]** As illustrated in Fig. 2, in a condition where the locking member 60 of the retarded angle locking portion 6A and the locking member 60 of the advanced angle locking portion 6B are protruded into the locking chamber 62, a lock state is achieved for restraining the displacement of the relative rotational phase between the inner rotor 1 and the outer rotor 2 at the predetermined lock phase, which is set between the most advanced angle phase (a phase illustrated in Fig. 6) and the most retarded angle phase. Regarding a valve opening and closing timing of the engine, the lock phase is set for obtaining a smooth startability of the engine.

**[0035]** The locking member 60 is retracted from the locking chamber 62 by supplying the operation fluid into the locking chamber 62 through the locking passage 63. More particularly, when the locking chamber 62 is filled with the operation fluid, because of a pressure of the operation fluid in the locking chamber 62, a biasing force, which is applied in a direction in which the locking member 60 is housed in the outer rotor 2 (a direction in which the locking member 60 is retracted from the locking chamber 62) is generated. In a condition where the biasing force generated by the pressure of the operation fluid becomes greater degree than the biasing force of the spring 61, which is applied in a direction in which the locking member 60 is protruded into the locking chamber 62, the locking member 60 is retracted from the locking chamber 62 as illustrated in Fig. 3. Accordingly, the locking mechanism 6 achieves an unlock state, which allows the displacement of the relative rotational phase between the inner rotor 1 and the outer rotor 2.

**[0036]** The fluid pressure circuit 7 includes an oil pump 70, a control valve 76, and an oil pan 75. The oil pump 70 supplies the operation fluid relative to the control valve 76 by means of a driving force of the engine, the control valve 76 controls supply and discharge of the operation fluid at plural ports by means of a control of a control unit 9 (ECU: Electric Control Unit), and the oil pan 75 stores the operation fluid therein. According to the embodiment of the present invention, an electromagnetic spool valve is used as the control valve 76 that operates and displaces a spool 76b against a spring 76g by means of an energization from the control unit 9 to a solenoid 76a.

**[0037]** A first port 76c of the control valve 76 is connected to the advanced angle passage 11 communicating with the advanced angle chamber 43, a second port 76d of the control valve 76 is connected to the retarded angle passage 10 communicating with the retarded angle chamber 42, and a third port 76e of the control valve 76 is connected to the locking passage 63 communicating with the locking chamber 62. Further, a drain port 76f of the control valve 76 is communicated with the oil pan 75.

**[0038]** By means of the control of the control unit 9, the control valve 76 controls, through the advanced angle passage 11 and the retarded angle passage 10, supply and discharge of the operation fluid relative to one of, or both of the advanced angle chamber 43 and the retarded angle chamber 42, and varies the relative position of the vane 5 in the fluid pressure chamber 40, and thereby controls the displacement of the relative rotational phase between the outer rotor 2 and the inner rotor 1 within the range from the most advanced angle phase (a phase in which a volume of the advanced angle chamber 43 is maximized) as illustrated in Fig. 6 to the most retarded angle phase (a phase in which a volume of the retarded angle chamber 42 is maximized) as illustrated in Fig. 5. Accordingly, the control valve 76 and the control unit 9 for controlling the control valve 76 both represent a phase control apparatus 71 according to the embodiment of the present invention.

**[0039]** According to the embodiment of the present invention, the control valve 76 also serves as a lock control

apparatus 72, which controls an operation for varying a position of the locking mechanism 6 between the lock state and the unlock state. More particularly, by means of the control of the control unit 9, the control valve 76 controls supply and discharge of the operation fluid relative to the locking chamber 62 through the locking passage 63, and controls the protruding operation and a retracting operation of the locking member 60 relative to the locking chamber 62.

**[0040]** As illustrated in Fig. 7, by controlling an amount of electricity supplied from the control unit 9 to the solenoid 76a, the control valve 76 of the fluid pressure circuit 7 controls a degree of a stroke of the spool 76b, and changes a spool position from position W1 to position W5, and thereby switches operations of supply, discharge (drain), and stop (close) of the operation fluid relative to the advanced angle chamber 43, the retarded angle chamber 42, and the locking chamber 62. According to the embodiment of the present invention, a control for the amount of electricity supplied to the solenoid 76a is performed by varying a duty value (%) of current for supplying to the solenoid 76e. The degree of the stroke of the spool 76b is proportional to the amount of electricity supplied to the solenoid 76a (the duty value of current). However the invention is not limited thereto. Alternatively, or in addition, the control for the amount of electricity supplied to the solenoid 76a may be performed by various methods such as, by varying a current value, by varying a duty value (%) of an electrical pressure, and by varying an electrical pressure value. Control operations of the control valve 76 at each predetermined spool position is explained with reference to Fig. 7. However, the control operation is not limited as described below, and variations and changes may be made by others.

**[0041]** In a condition where the spool position is at the position W1, the control valve 76 supplies the operation fluid into the locking chamber 62, retracts the locking member 60 from the locking chamber 62, and makes the locking mechanism 6 into a unlock state. Further, by supplying the operation fluid into the retarded angle chamber 42 while draining the operation fluid from the advanced angle chamber 43, the control valve 76 performs a retarded angle direction displacement operation for displacing the relative rotational phase between the outer rotor 2 and the inner rotor 1 in a retarded angle direction S1.

**[0042]** In a condition where the spool position is at position W2, the control valve 76 stops supply and discharge of the operation fluid relative to both of the advanced angle chamber 43 and the retarded angle chamber 42 (closes the first port 76c and the second port 76d), and performs a phase holding operation for holding the relative rotational phase between the outer rotor 2 and the inner rotor 1 at a given time at a given position.

**[0043]** In a condition where the spool position is at position W3, the control valve 76 supplies the operation fluid into the locking chamber 62, and makes the locking mechanism 6 into the unlock state. Further, by supplying the operation fluid into the advanced angle chamber 43 while draining the operation fluid from the retarded angle chamber 42, the control valve 76 performs an advanced angle direction displacement operation for displacing the relative rotational phase between the outer rotor 2 and the inner rotor 1 in an advanced angle direction S2.

**[0044]** In a condition where the spool position is at position W4, the control valve 76 drains the operation fluid from the locking chamber 62, and when the relative rotational phase becomes the lock phase, the control valve 76 makes the locking mechanism 6 into a lockable position. Further, the control valve 76 supplies the operation fluid into the advanced angle chamber 43 while draining the operation fluid from the retarded angle chamber 42. Thereby, the control valve 76 performs an advanced angle biasing operation for biasing the relative rotational phase in the advanced angle direction S2 in a condition where the locking mechanism 6 is at the lockable position. This operation is performed, as described below, for making the relative rotational phase into the lock phase and making the locking mechanism 6 into the lock state in a starting point control.

**[0045]** In a condition where the spool position is at the position W5, a drain operation is performed for making a condition in which the operation fluid of the advanced angle chamber 43, the retarded angle chamber 42, and the locking chamber 62 can be discharged to the oil pan 75. Because of this operation, all of the first port 76c, the second port 76d, and the third port 76e of the control valve 76 communicate with the drain port 76f.

**[0046]** As illustrated in Fig. 8, the control unit 9 includes a central processing unit 91 (i.e., a CPU) for calculation, a memory 92 for storing predetermined programs, data tables, or the like, an input/output interface 93. The control unit 9 receives signals detected by various sensors such as a cam angle sensor 101 for detecting a camshaft phase, a crank angle sensor 102 for detecting a crankshaft phase, an ignition switch 103, a fluid temperature sensor 104 for detecting a temperature of the operation fluid, a rotational speed sensor 105 for detecting a rotational speed of the crankshaft (a rotational speed of the engine), a coolant temperature sensor 106 for detecting a temperature of a cooling water of the engine. The control unit 9 further receives the signals detected by various sensors such as a vehicle speed sensor (not shown) and a throttle angle sensor (not shown). On the basis of the signals detected by the various sensors, the control unit 9 detects operating conditions of the engine.

**[0047]** On the basis of a phase of the camshaft 3 detected by the cam angle sensor 101 and a phase of the crankshaft detected by the crank angle sensor 102, the control unit 9 can calculate a present value of a relative rotational phase between the camshaft 3 and the crankshaft (i.e., the relative rotational phase between the inner rotor 1 and the outer rotor 2 of the valve timing control apparatus).

**[0048]** On the basis of operating conditions of the engine such as a temperature of an engine fluid, a rotational

speed of the crankshaft, a vehicle speed, a throttle angle, or the like, detected by the various sensors, the control unit 9 controls the amount of electricity supplied to the control valve 76. Thereby, the control unit 9 controls supply and discharge of the operation fluid relative to the advanced angle chamber 43, the retarded angle chamber 42, and the locking chamber 62, by means of the control valve 76. Accordingly the control unit 9 appropriately varies the relative rotational phase between the inner rotor 1 and the outer rotor 2, and conditions of the locking mechanism 6 so as to be suitable for the operating conditions of the engine of that time.

**[0049]** With reference to a flowchart illustrated in Fig. 9, an operation control of the valve timing control apparatus according to the embodiment of the present invention is explained by focusing a control at a starting of the engine (the starting point control).

**[0050]** When the control unit 9 receives an engine starting signal from the ignition switch 103, cranking is started (step S1: YES). Then, the control unit 9 changes the spool position of the control valve 76 to the position W5 for performing a drain operation so that the operation fluid in both of the advanced angle chamber 43 and the retarded angle chamber 42 is drainable (step S2). At the position W5, the operation fluid in the locking chamber 62 is also drainable. In this condition, by means of the torque fluctuation supplied to the camshaft 3 during cranking, the vane 5 is oscillated in the advanced angle direction and in the retarded angle direction one after the other. In case the advanced angle chamber 43 and the retarded angle chamber 42 are filled with the operation fluid at a starting of cranking, by means of an oscillation of the vane 5, the operation fluid in the advanced angle chamber 43 and the retarded angle chamber 42 is discharged. Thereby, a facility of an operation of the vane 5 by means of the torque fluctuation, i.e., a flexibility of the oscillation and the displacement of the relative rotational phase between the outer rotor 2 and the inner rotor 1 can be well ensured.

**[0051]** The torque fluctuation applied to the camshaft 3 during cranking in the retarded angle direction is larger degree than that of in the advanced angle direction. Further, the torque setting of the torsion spring 27 is set in such a manner not to interrupt the displacement of the relative rotational phase in the retarded direction. Therefore, when the flexibility of the oscillation and the displacement of the relative rotational phase is ensured, the relative rotational phase is displaced relatively in the retarded angle direction while oscillating during cranking. Accordingly, when the relative rotational phase at the starting of cranking is positioned at the advanced angle side position relative to the lock phase, the relative rotational phase is displaced in the retarded angle direction by means of the torque fluctuation and achieves the lock phase during cranking. On this occasion, because the operation fluid in the locking chamber 62 is also drainable, the locking mechanism 6 comes into the lock state when the relative rotational phase reaches the lock phase. Thereby a condition is achieved where the engine can be well started. Then, when the engine is started (step S3: YES), a control after an engine starting is started (step S7).

**[0052]** Fig. 10 illustrates an example in case the relative rotational phase at the starting of cranking is positioned at the advanced angle side position relative to the lock phase. A timing chart illustrated in Fig. 10 indicates an operation of the valve timing control apparatus according to the embodiment of the present invention in a condition where the relative rotational phase at the starting of cranking is positioned at the most advanced angle phase as shown in Fig. 6. In this case, when the engine starting signal is inputted, the crankshaft is rotated by means of an electrical motor, or the like, and then cranking is started, and thereby the relative rotational phase is displaced relatively in the retarded angle direction while oscillating by means of the torque fluctuation applied to the camshaft 3. Then, the locking mechanism 6 comes into the lock state when the relative rotational phase reaches the lock phase, and the relative rotational phase is thereby restrained at the lock phase. Fig. 10 illustrates an example in case the advanced angle chamber 43 and the retarded angle chamber 42 are filled with operation fluid at the starting of cranking, and an oscillation level of the relative rotational phase is increased in response to a degree of the operation fluid to be discharged from the advanced angle chamber 43 and the retarded angle chamber 42 by means of the oscillation of the vane 5.

**[0053]** According to Fig. 10, the spool position of the control valve 76 is changed to the position W4 after a predetermined period of time T is elapsed. However, normally, the relative rotational phase is restrained at the lock phase and the engine is started (step S3: YES) before the predetermined period of time T is elapsed, and the operation control of the valve timing control apparatus progresses the control after the engine starting (step S7). Therefore, a control after a termination of the predetermined period of time T (step S5), is not usually performed.

**[0054]** In contrast, when the relative rotational phase at the starting of cranking is positioned at the retarded angle side position relative to the lock phase, even if the relative rotational phase is displaced in the retarded angle direction by means of the torque fluctuation applied to the camshaft 3 during cranking, because the lock phase is positioned in the advanced angle side relative to the present relative rotational phase, the locking mechanism 6 does not come into the lock state. On this occasion, the relative rotational phase is oscillated in the vicinity of the most retarded angle phase. In such a condition, a startability of the engine may be adversely affected, and the engine may occasionally fail to start.

**[0055]** In a condition where the engine is not started (step S3: NO) and the predetermined period of time T is elapsed (step S4: YES), the control unit 9 changes the spool position of the control valve 76 to the position W4 and performs the advanced angle biasing operation, and supplies the operation fluid into the advanced angle

chamber 43 while draining the operation fluid from the retarded angle chamber 42 (step S5). On this occasion, the operation fluid of the locking chamber 62 is also drained. Therefore, the relative rotational phase is displaced relatively in the retarded angle direction by means of the pressure of the operation fluid supplied into the advanced angle chamber 43 while oscillating by means of the torque fluctuation applied to the camshaft 3 during cranking. Accordingly, when the relative rotational phase at the starting of cranking is positioned at the retarded angle side position relative to the lock phase, the relative rotational phase is displaced in the advanced angle direction by means of the pressure of the operation fluid supplied in the advanced angle chamber 43 and achieves the lock phase. On this occasion, because the operation fluid in the locking chamber 62 is also dischargeable, the locking mechanism 6 comes into the lock state when the relative rotational phase reaches the lock phase. Thereby the condition in which the engine can be well started is achieved. Then, when the engine is started (step S6: YES), the control after the engine starting is started (step S7).

**[0056]** The predetermined period of time T is set, in a condition where cranking is started with the advanced angle chamber 43 and the retarded angle chamber 42 filled with the operation fluid longer than, or equal to, a time required for a center of the oscillation of the relative rotational phase during cranking to be displaced to the lock phase from the most advanced angle phase. In other words, the predetermined period of time T is set, in a condition where the lock phase is positioned in a direction (retarded angle direction) in which the relative rotational phase is displaced by means of the torque fluctuation applied to the camshaft 3 during cranking relative to the relative rotational phase at the starting of cranking (in a condition where the relative rotational phase at the starting of cranking is positioned at the advanced angle side position relative to the lock phase) longer than, or equal to, an estimated longest time required for the relative rotational phase to be displaced to the lock phase by means of the torque fluctuation. According to the embodiment of the present invention, the valve timing control apparatus at the estimated longest time is in a condition where the advanced angle chamber 43 and the retarded angle chamber 42 are filled with the operation fluid, and the relative rotational phase is positioned at the most advanced angle phase. The predetermined period of time T can be statistically calculated by means of a regression analysis on the basis of a test.

**[0057]** Fig. 11 illustrates an example in case of the relative rotational phase at the starting of cranking is positioned at the retarded angle side position relative to the lock phase. A timing chart illustrated in Fig. 11 indicates an operation of the valve timing control apparatus according to the embodiment of the present invention in a condition where the relative rotational phase at the starting of cranking is positioned at the most retarded angle phase as shown in Fig. 5. In this case, when the engine starting signal is inputted, the crankshaft is rotated by means of an electrical motor, or the like, and then cranking is started. According to this operation, the relative rotational phase is oscillated by means of the torque fluctuation applied to the camshaft 3. However, because the relative rotational phase cannot be displaced in the retarded direction more than the present position, the relative rotational phase is oscillated in the vicinity of the most retarded angle phase. Therefore, on this occasion, the relative rotational phase does not reach the lock phase. Thus, after the predetermined period of time T is elapsed, the control unit 9 changes the spool position of the control valve 76 to the position W4 (step S5). Thereby, the relative rotational phase is displaced relatively in the advanced angle direction by means of the pressure of the operation fluid supplied into the advanced angle chamber 43 while oscillating by means of the torque fluctuation. Then, when the relative rotational phase reaches the restriction phase, the locking member 60 of the locking mechanism 6 protrudes and engages with the restricting step portion 64, and thereby the displacement of the relative rotational phase in the retarded direction is restricted. Further, the locking mechanism 6 comes into the lock state when the relative rotational phase is displaced in the advanced angle direction and reached the lock phase. Thereby the relative rotational phase is restrained at the lock phase and the condition in which the engine can be well started is achieved. Then, when the engine is started (step S6: YES), the control after the engine starting is started (step S7). Fig. 11 illustrates an example in case cranking is started with the advanced angle chamber 43 and the retarded angle chamber 42 are filled with the operation fluid, and the oscillation level of the relative rotational phase is increased in response to a degree of the operation fluid to be discharged from the advanced angle chamber 43 and the retarded angle chamber 42 by means of the oscillation of the vane 5.

**[0058]** According to the embodiment of the present invention, by means of the torque fluctuation applied to the camshaft 3 during cranking, the relative rotational phase between the outer rotor 2 and the inner rotor 1 is displaced relatively in the retarded angle direction while oscillating. However the invention is not limited thereto. Alternatively, or in addition, the relative rotational phase may be displaced relatively in the advanced angle direction while oscillating during cranking by means of the torque fluctuation applied to the camshaft 3 during cranking. In such a case the torsion spring 27 is provided for biasing the relative rotational phase in the retarded angle direction. The aforementioned explanation for the operation control at the starting of the engine (the starting point control) can be applied to this variation on a condition that the words advanced and retarded are switched.

**[0059]** According to the embodiment of the present invention, the locking chamber 62 is provided with, at the retarded angle side, the restricting step portion 64. The restricting step portion 64, at the restriction phase defined between the most retarded angle phase and the lock

phase, restricts the displacement of the relative rotational phase to the retarded angle side from the restriction phase, and allows the displacement of the relative rotational phase to the advanced angle side. Thereby, a reliability of a restraint of the relative rotational phase by means of the locking mechanism 6 can be improved. However the invention is not limited thereto. Alternatively, or in addition, the valve timing control apparatus may be configured without the restricting step portion 64. It is because, according to the embodiment of the present invention, the displacement of the rotational phase from the most retarded angle phase to the lock phase can be certainly performed by forcibly displacing the relative rotation in the advanced angle direction by supplying the operation fluid into the advanced angle chamber 43 after the predetermined period of time T is elapsed.

**[0060]** According to the embodiment of the present invention, during the predetermined period of time after the staring of cranking, the cranking is performed in a condition where the operation fluid in both of the advanced angle chamber and the retarded angle chamber is drainable. Therefore, by means of the oscillation of the relative rotational phase, the relative rotational phase can be displaced in one of the advanced angle direction and the retarded angle direction while draining the operation fluid from the advanced angle chamber and the retarded angle chamber. Accordingly, in a condition where the lock phase is positioned at one of the advanced angle side and the retarded angle side relative to the relative rotational phase at the starting of cranking, the relative rotational phase can be restrained by means of the locking mechanism. In contrast, in a condition where the lock phase is not positioned at the one of the advanced angle side and the retarded angle side, the operational fluid is supplied into one of the advanced angle chamber and the retarded angle chamber for displacing the relative rotational phase to the other of the advanced angle side and the retarded angle side after the predetermined period of time is elapsed, thus the relative rotational phase can be restrained by means of the locking mechanism. Accordingly, the reliability of the restraint of the relative rotational phase by means of the locking mechanism at the starting of the internal combustion engine can be improved.

**[0061]** The present invention is applicable as long as the predetermined period of time is set, in a condition where cranking is started with the fluid pressure chamber filled with the operation fluid, longer than, or equal to, the time required for the center of the oscillation of the relative rotational phase during cranking to be displaced to the lock phase from one of the most advanced angle phase and the most retarded angle phase positioned in the other of the advanced angle direction and the retarded angle direction. In such a condition, the relative rotational phase can certainly be reached to the lock phase in a condition where the lock phase is positioned at the one of the advanced angle side and the retarded angle side. Accordingly, the reliability of the restraint by means of the locking mechanism can be improved.

**[0062]** The present invention is applicable as long as the phase control apparatus discontinues the starting point control when the internal combustion engine is started, and starts the control after the engine starting.

It is explicitly stated that all features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original disclosure as well as for the purpose of restricting the claimed invention independent of the composition of the features in the embodiments and/or the claims. It is explicitly stated that all value ranges or indications of groups of entities disclose every possible intermediate value or intermediate entity for the purpose of original disclosure as well as for the purpose of restricting the claimed invention, in particular as limits of value ranges.

## Claims

**1.** A valve timing control apparatus comprising:

a driving side rotational member (2) synchronously rotated with a crankshaft;
a driven side rotational member (1) provided coaxially with the driving side rotational member and synchronously rotated with a camshaft (3);
a fluid pressure chamber (40) formed on at least one of the driving side rotational member and the driven side rotational member, the fluid pressure chamber being separated into an advanced angle chamber (43) and a retarded angle chamber (42);
a phase control apparatus (9, 71, 76) controlling an operation fluid to be supplied to and discharged from one of, or both of the advanced angle chamber and the retarded angle chamber, for displacing a relative rotational phase between the driving side rotational member and the driven side rotational member within a range from a most advanced angle phase to a most retarded angle phase; and
a locking mechanism (6) restraining the relative rotational phase between the driving side rotational member and the driven side rotational member at a lock phase between the most advanced angle phase and the most retarded angle phase, **characterized in that**
during cranking, the relative rotational phase is displaced relatively in one of an advanced angle direction and a retarded angle direction while oscillating, and
the phase control apparatus performs a starting point control for discharging the operation fluid from the advanced angle chamber and the retarded angle chamber during a predetermined period of time after a starting of cranking, and

supplying the operation fluid into one of the advanced angle chamber and the retarded angle chamber for displacing the relative rotational phase to the other of the advanced angle direction and the retarded angle direction after the predetermined period of time is elapsed.

**2.** The valve timing control apparatus according to claim 1, wherein
the predetermined period of time is set, in a condition where cranking is started with the fluid pressure chamber filled with the operation fluid, longer than, or equal to, a time required for a center of an oscillation of the relative rotational phase during cranking to be displaced to the lock phase from one of the most advanced angle phase and the most retarded angle phase positioned in the other of the advanced angle direction and the retarded angle direction.

**3.** The valve timing control apparatus according to claim 1 or 2, wherein
the phase control apparatus discontinues the starting point control when the internal combustion engine is started, and starts a control after an engine starting.

**4.** The valve timing control apparatus according to claim 1, 2 or 3 wherein
The phase control apparatus includes:

a biasing mechanism (27) set for displacing the relative rotational phase between the driving side rotational member and the driven side rotational member to the advanced angle direction, wherein
by means of the biasing mechanism and a pressure of the operation fluid supplied into one of the advanced angle chamber and the retarded angle chamber, the phase control apparatus displaces the relative rotational phase relatively in one of the advanced angle direction and the retarded angle direction while oscillating during cranking.

FIG. 1

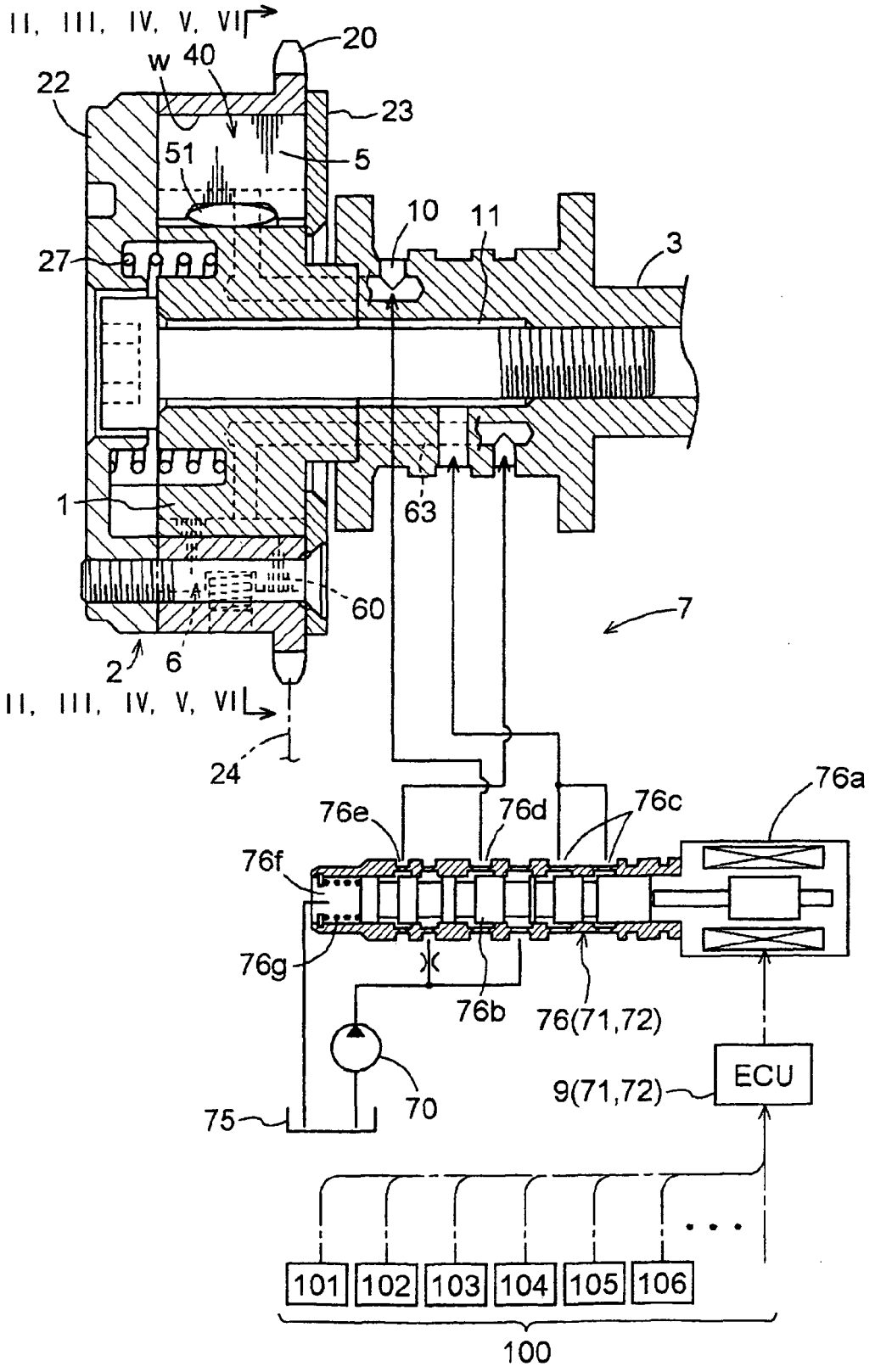

II, III, IV, V, VI
20
w
40
22
23
51
5
10
11
3
27
1
63
60
7
2
6
II, III, IV, V, VI
24
76a
76e
76d
76c
76f
76g
76b
76(71,72)
ECU
9(71,72)
70
75
101
102
103
104
105
106
100

FIG. 2

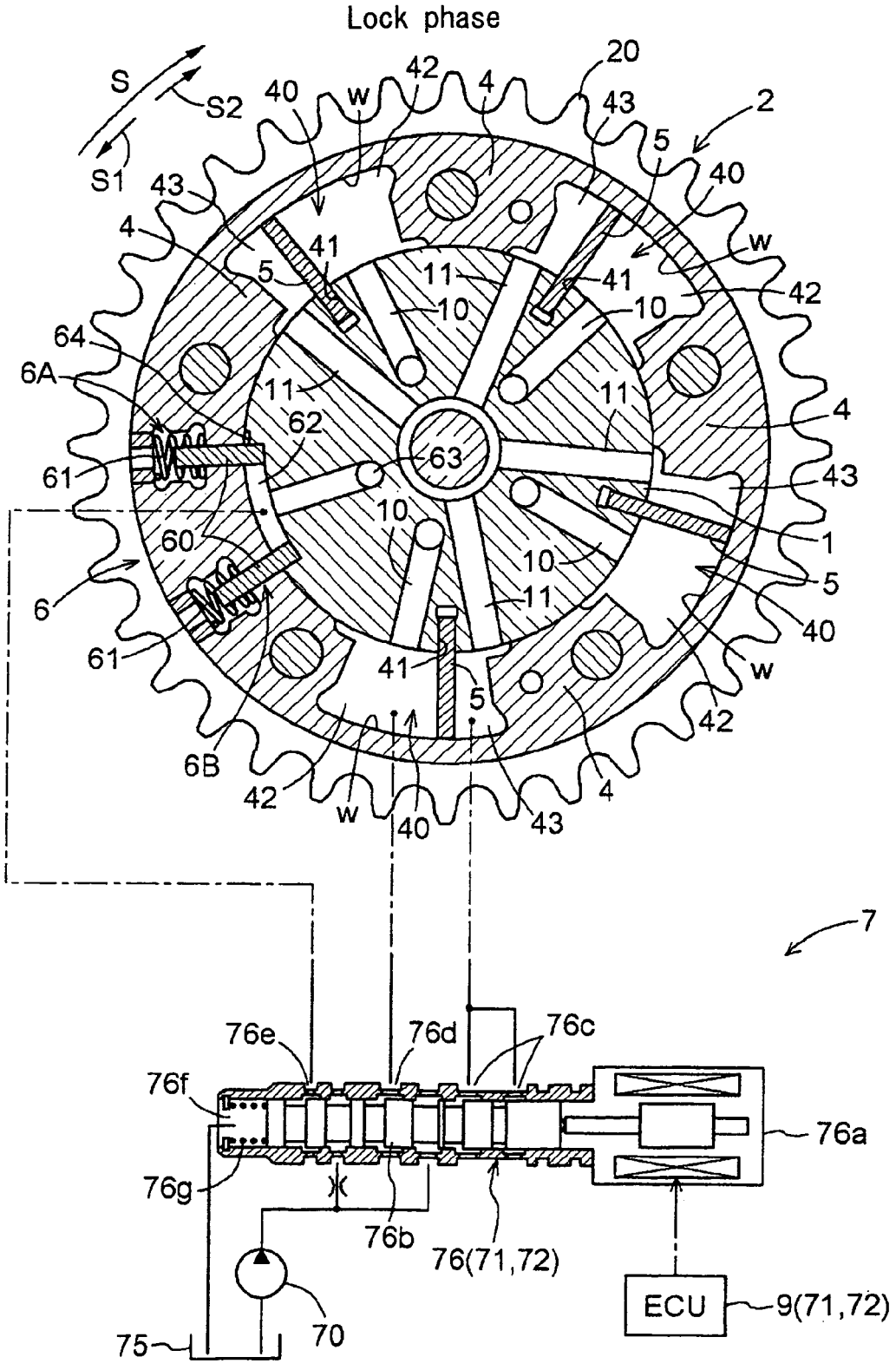

Lock phase
S
S2
S1
20
42
40
w
4
43
2
5
41
11
10
64
6A
62
63
61
60
6
6B
1
7
76e
76d
76c
76f
76a
76g
76b
76(71,72)
ECU
9(71,72)
75
70

FIG. 3

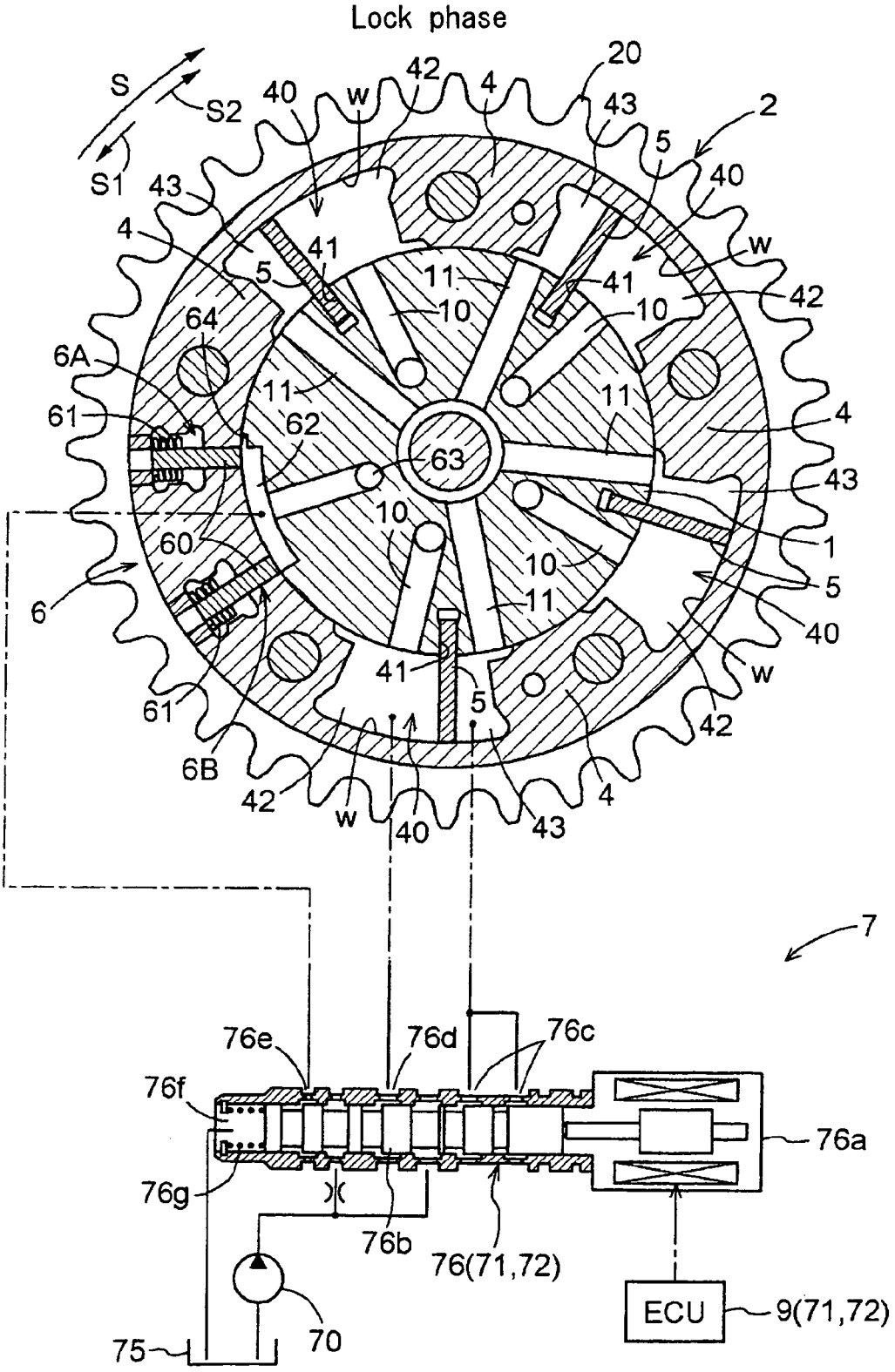

Lock phase
S
S2
S1
20
42
40
w
4
43
2
5
41
11
10
64
6A
61
62
63
60
6
6B
1
7
76e
76d
76c
76f
76a
76g
76b
76(71,72)
ECU
9(71,72)
75
70

FIG. 4

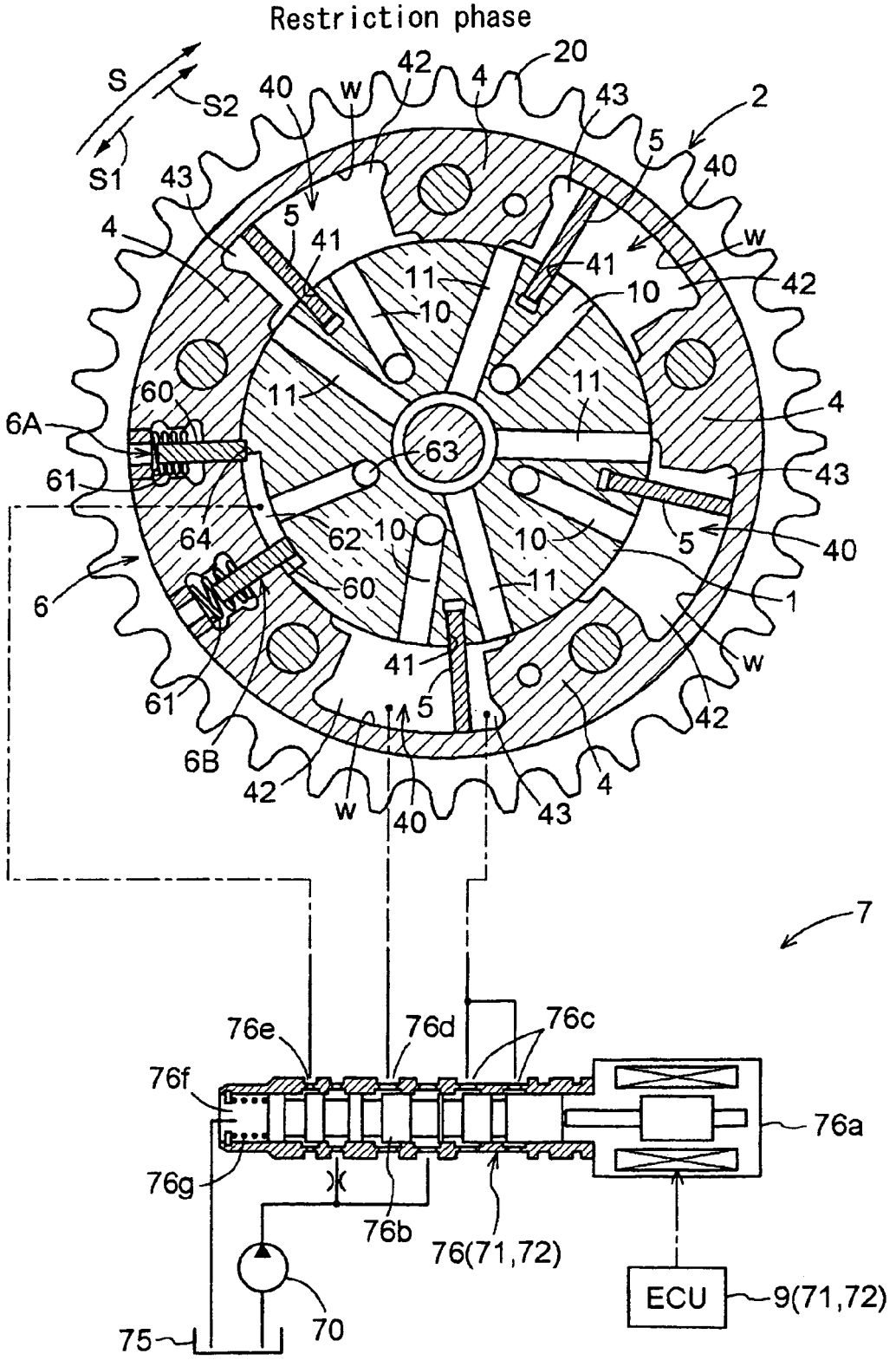

Restriction phase
S
S2
S1
20
42
40
w
4
43
2
5
41
11
10
60
6A
61
63
64
62
6
6B
7
76e
76d
76c
76f
76a
76g
76b
76(71,72)
ECU
9(71,72)
75
70

FIG. 5

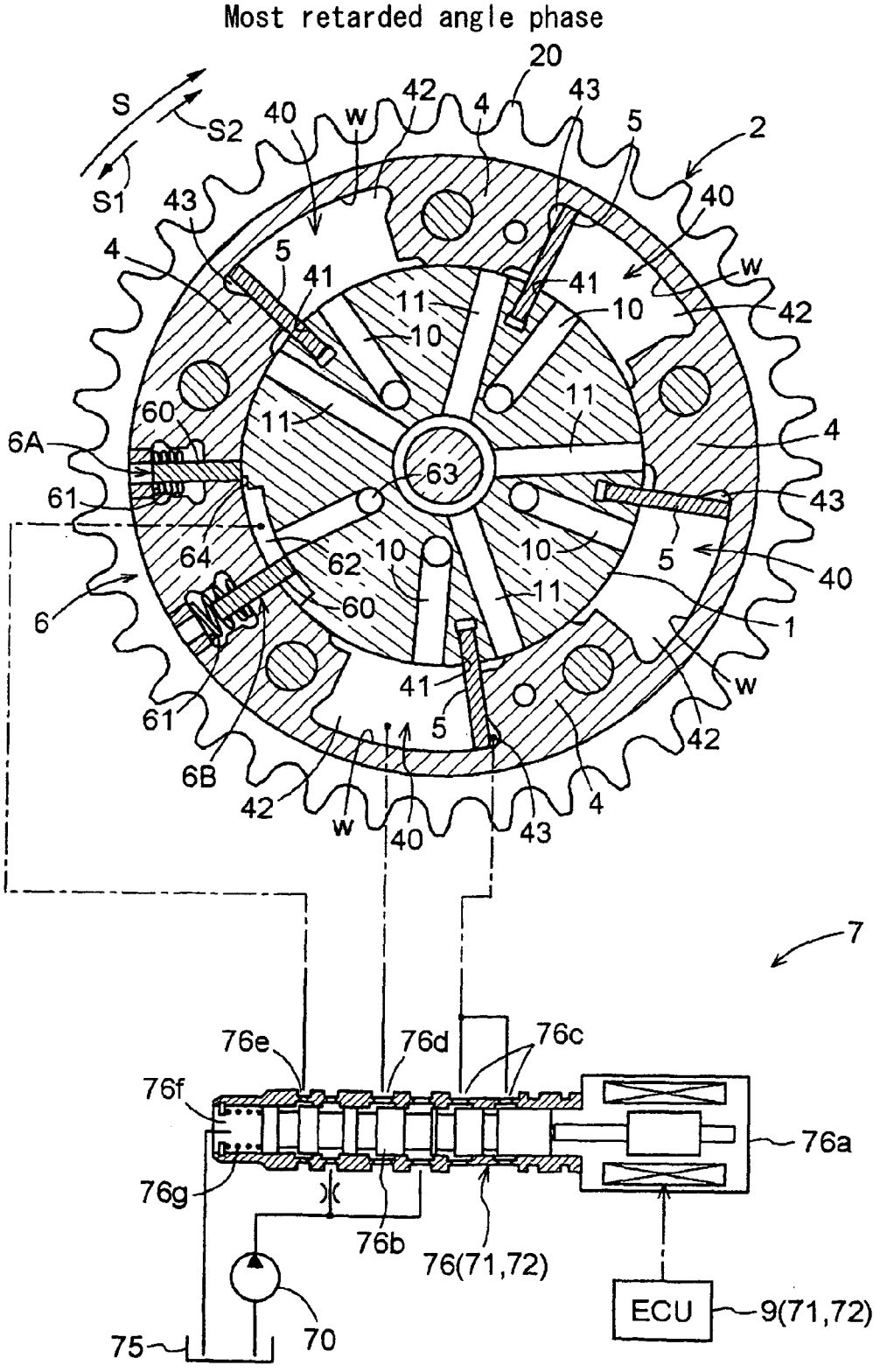

Most retarded angle phase
S
S2
S1
20
40
w
42
4
43
5
2
11
10
41
60
6A
61
63
64
62
6
6B
7
76e
76d
76c
76f
76a
76g
76b
76(71,72)
ECU
9(71,72)
75
70

FIG. 6

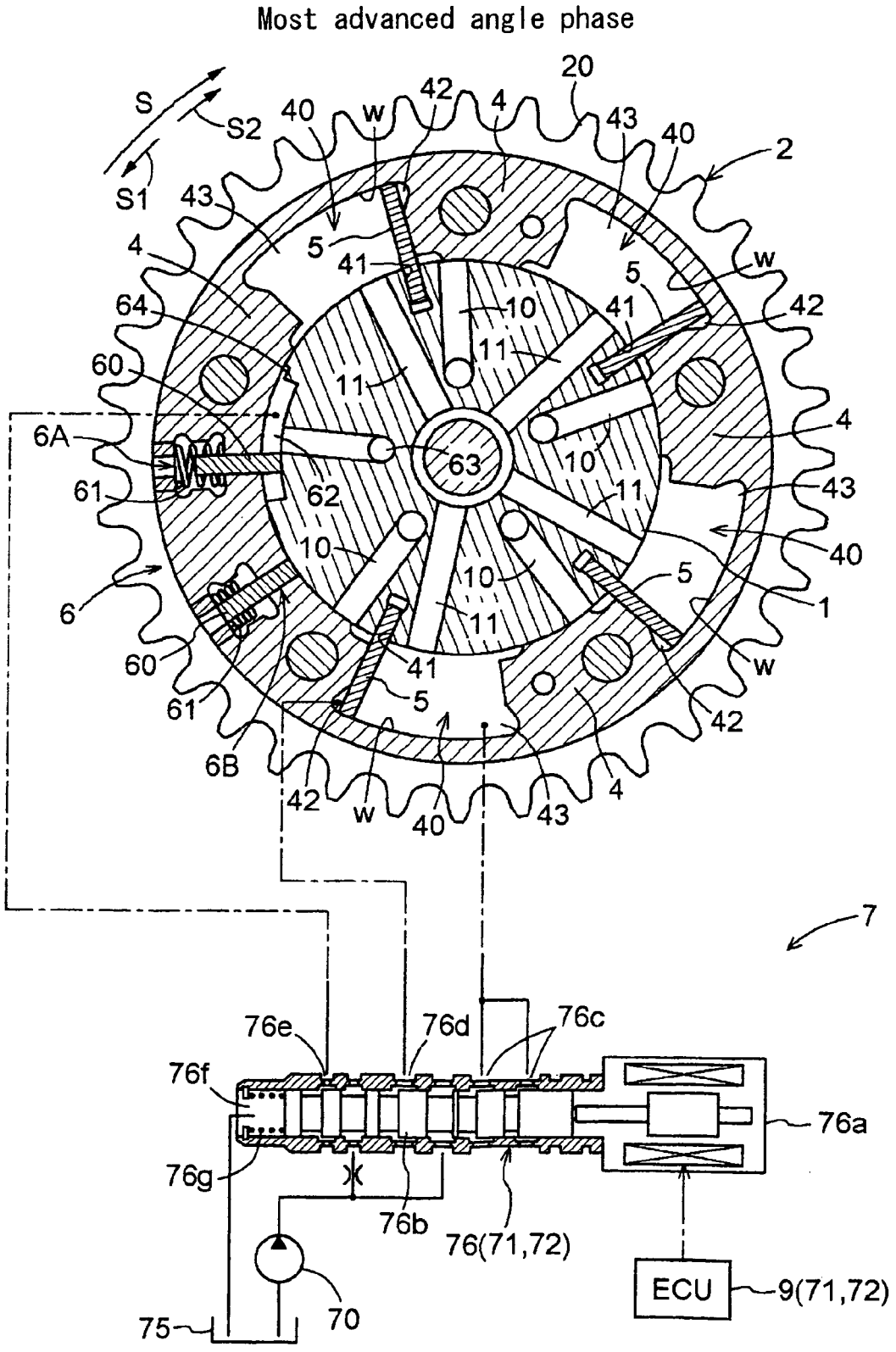

Most advanced angle phase
S
S2
S1
20
2
40
w
42
4
43
5
41
64
60
6A
61
62
63
10
11
6
6B
7
76e
76d
76c
76f
76g
76a
76b
76(71,72)
70
75
ECU
9(71,72)

FIG. 7

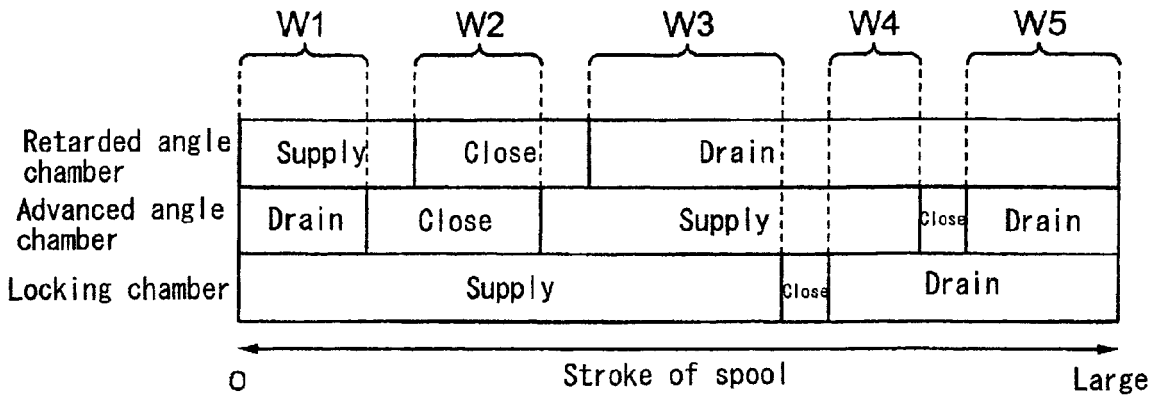

W1
W2
W3
W4
W5
Retarded angle chamber
Advanced angle chamber
Locking chamber
Supply
Close
Drain
Drain
Close
Supply
Close
Drain
Supply
Close
Drain
0
Stroke of spool
Large

FIG. 8

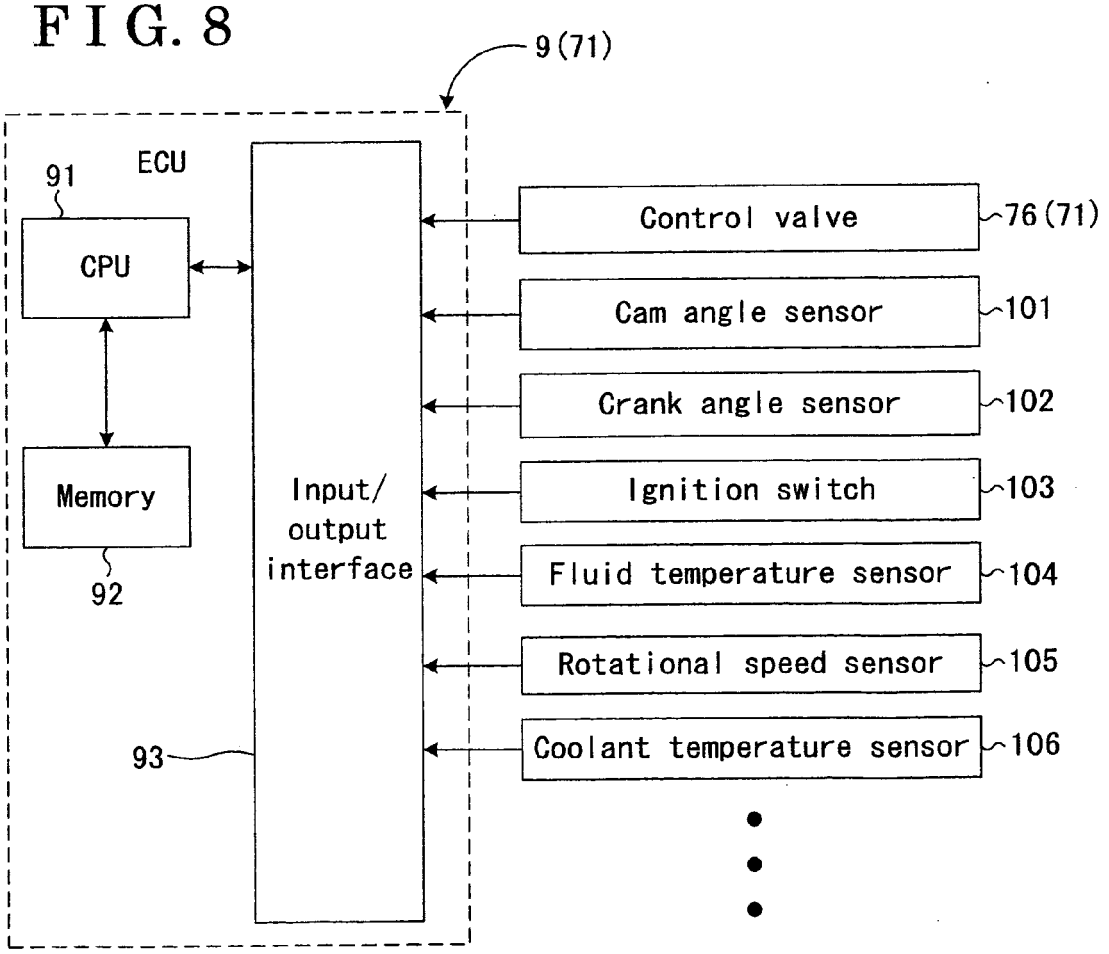

9(71)
ECU
91
CPU
Memory
92
93
Input/ output interface
Control valve
76(71)
Cam angle sensor
101
Crank angle sensor
102
Ignition switch
103
Fluid temperature sensor
104
Rotational speed sensor
105
Coolant temperature sensor
106

FIG. 9

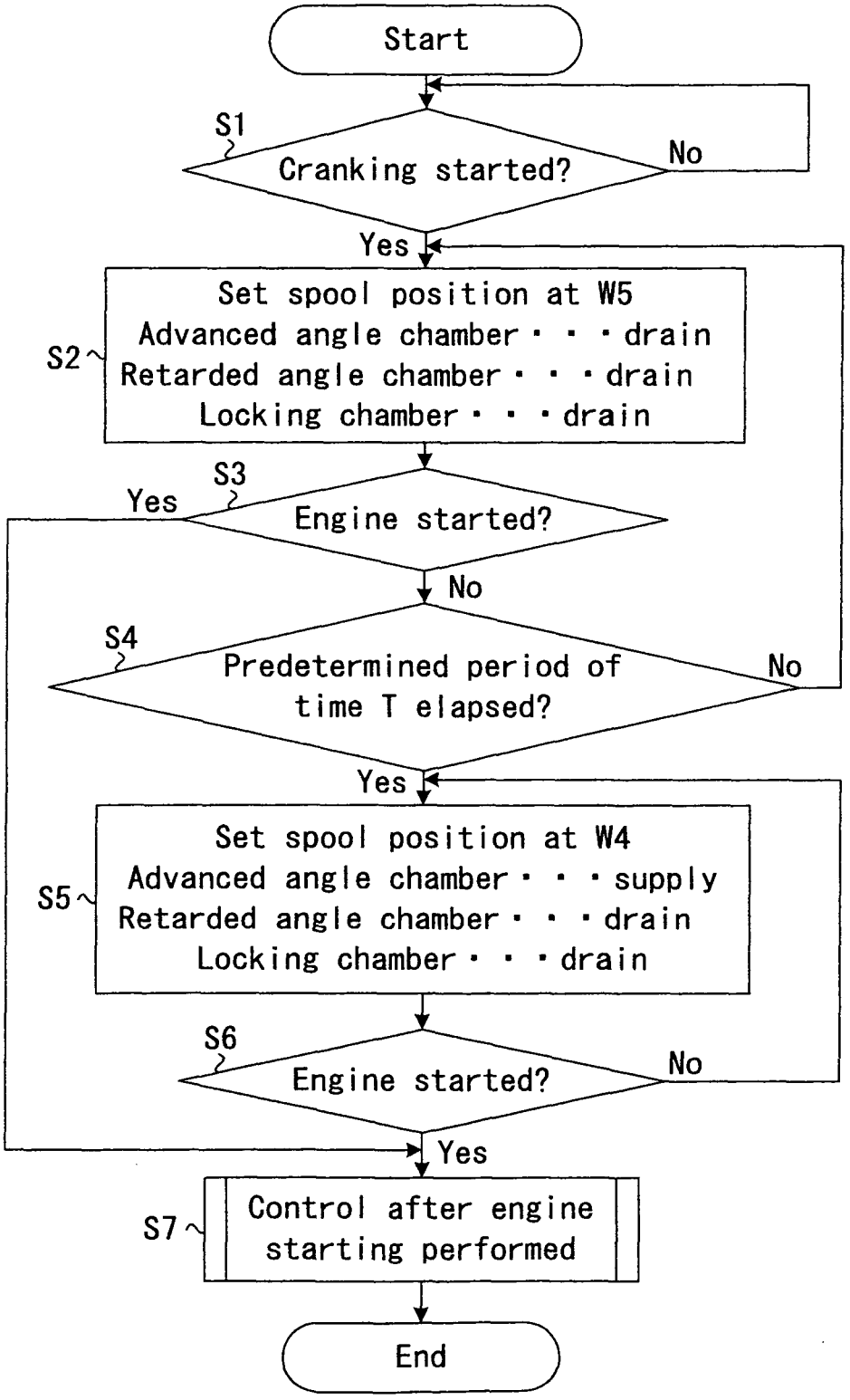

Start
S1
Cranking started?
No
Yes
S2
Set spool position at W5
Advanced angle chamber ・・・drain
Retarded angle chamber ・・・drain
Locking chamber ・・・drain
S3
Yes
Engine started?
No
S4
Predetermined period of time T elapsed?
No
Yes
S5
Set spool position at W4
Advanced angle chamber ・・・supply
Retarded angle chamber ・・・drain
Locking chamber ・・・drain
S6
Engine started?
No
Yes
S7
Control after engine starting performed
End

FIG. 10

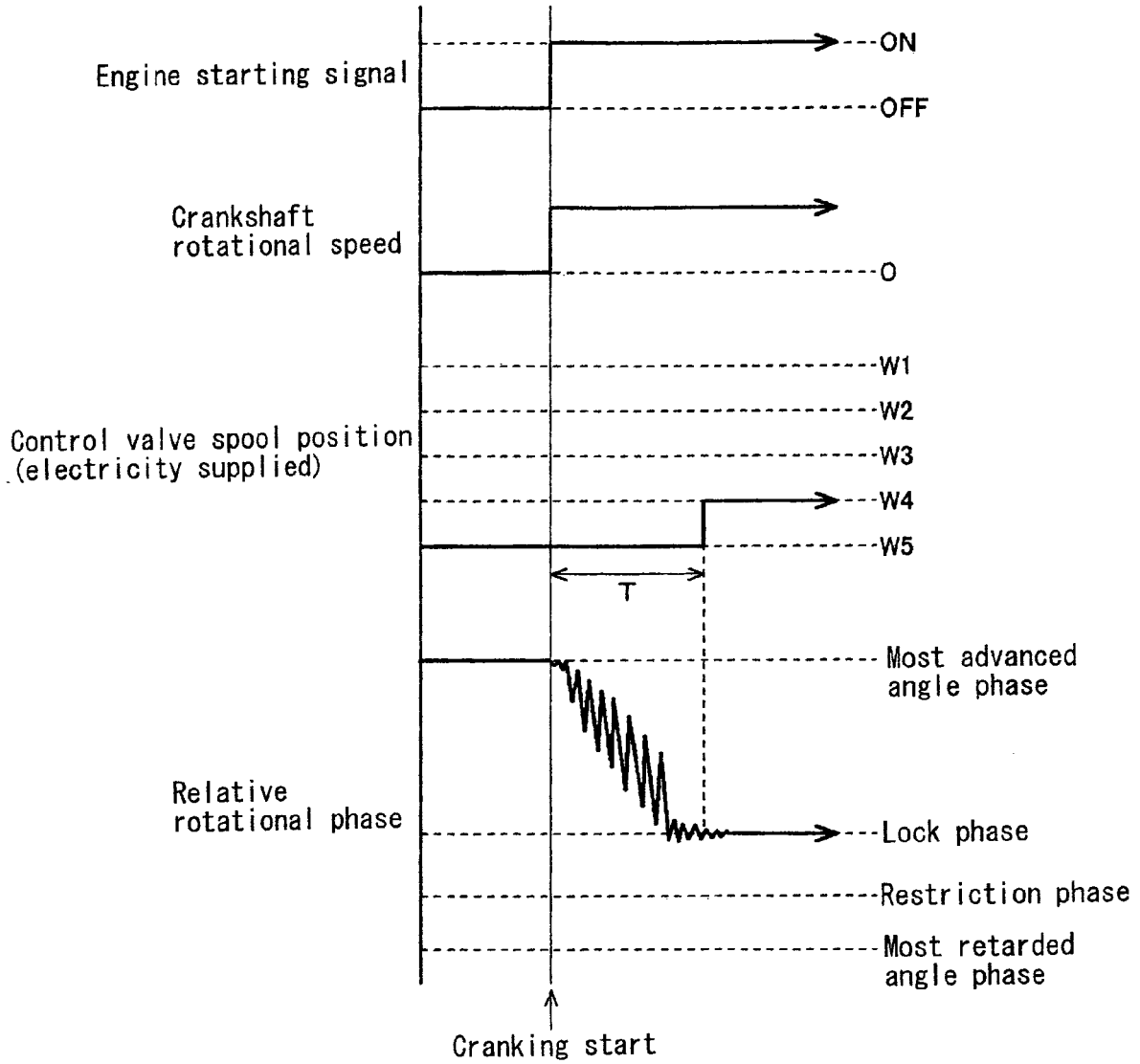
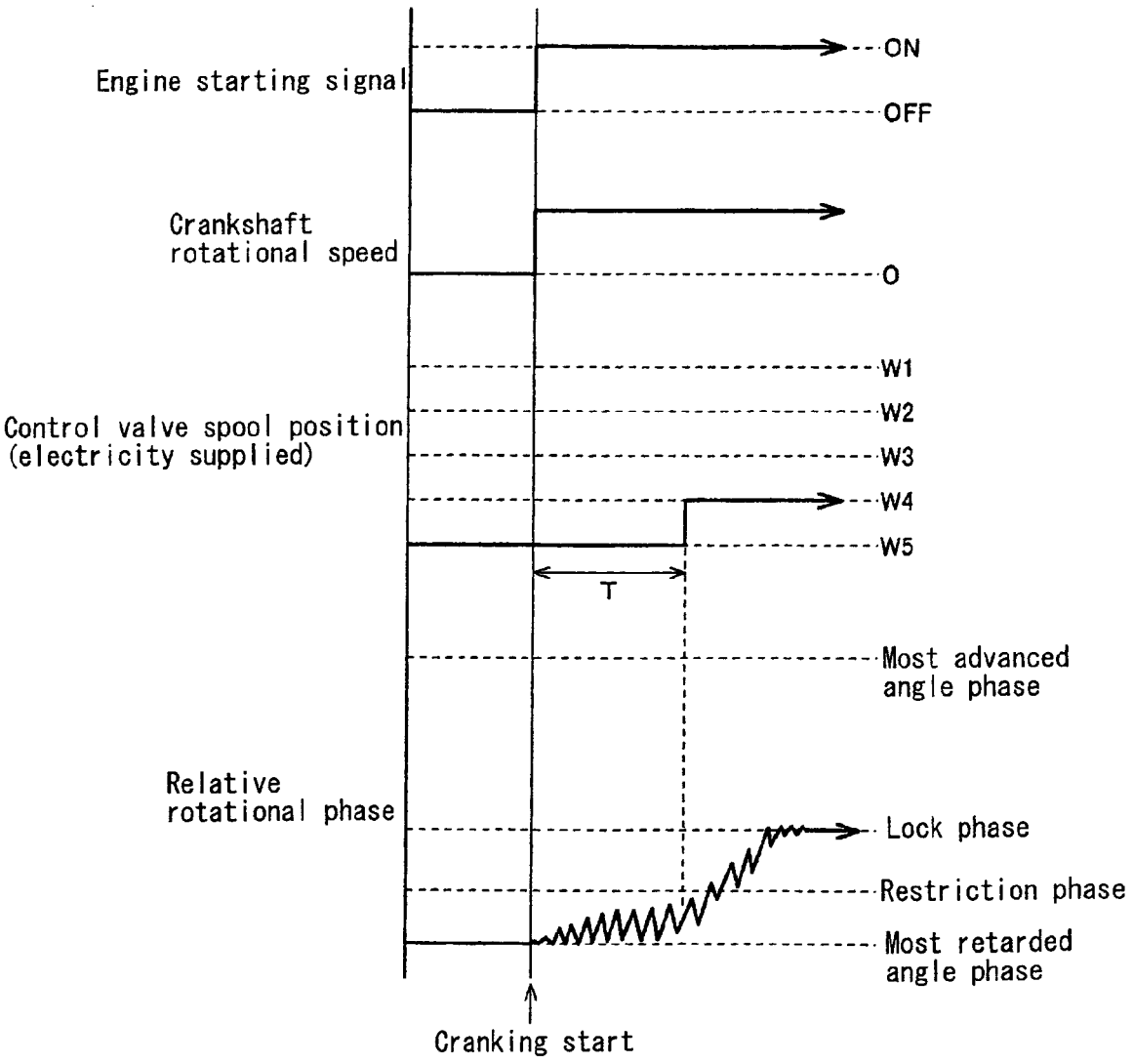

Engine starting signal
ON
OFF
Crankshaft rotational speed
0
Control valve spool position (electricity supplied)
W1
W2
W3
W4
W5
T
Most advanced angle phase
Relative rotational phase
Lock phase
Restriction phase
Most retarded angle phase
Cranking start

FIG. 11


Engine starting signal
ON
OFF
Crankshaft rotational speed
0
Control valve spool position (electricity supplied)
W1
W2
W3
W4
W5
T
Most advanced angle phase
Relative rotational phase
Lock phase
Restriction phase
Most retarded angle phase
Cranking start

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 05 02 6370

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| A | US 2002/017255 A1 (OGAWA KAZUMI)<br>14 February 2002 (2002-02-14)<br>* paragraphs [0056], [0057] * | 1 | INV.<br>F01L1/344 |
| A | US 6 035 819 A (NAKAYOSHI ET AL)<br>14 March 2000 (2000-03-14)<br>* column 8, lines 42-67; figure 4 * | 1 | |
| D,A | PATENT ABSTRACTS OF JAPAN<br>vol. 2002, no. 08,<br>5 August 2002 (2002-08-05)<br>& JP 2002 097912 A (AISIN SEIKI CO LTD),<br>5 April 2002 (2002-04-05)<br>* abstract * | 1-6 | |
| A | US 2003/121486 A1 (KOMAZAWA OSAMU ET AL)<br>3 July 2003 (2003-07-03)<br>* paragraphs [0061], [0063]; figures 2,4 * | 1 | |
| A | US 2002/038640 A1 (FUJIWAKI KENJI ET AL)<br>4 April 2002 (2002-04-04)<br>* paragraphs [0059] - [0061]; figure 2 * | 1 | TECHNICAL FIELDS SEARCHED (IPC)<br>F01L |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 6 April 2006 | Clot, P |

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 02 6370

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06-04-2006

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2002017255 A1 | 14-02-2002 | DE 10128694 A1 | 20-12-2001 |
| | | JP 2001355468 A | 26-12-2001 |
| US 6035819 A | 14-03-2000 | DE 19903624 A1 | 12-08-1999 |
| | | JP 11280428 A | 12-10-1999 |
| JP 2002097912 A | 05-04-2002 | DE 10147336 A1 | 02-05-2002 |
| | | US 2002038640 A1 | 04-04-2002 |
| US 2003121486 A1 | 03-07-2003 | DE 10256992 A1 | 17-07-2003 |
| | | JP 2003172109 A | 20-06-2003 |
| US 2002038640 A1 | 04-04-2002 | DE 10147336 A1 | 02-05-2002 |
| | | JP 2002097912 A | 05-04-2002 |

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