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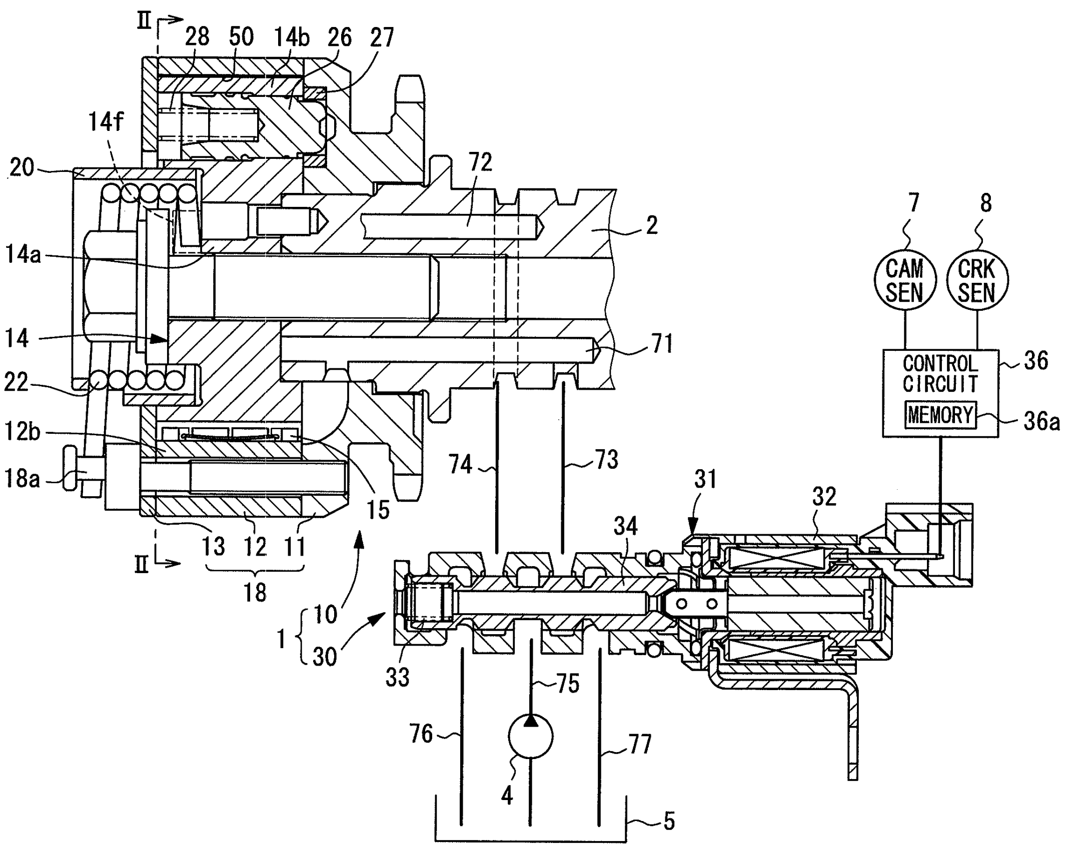
(54) Valve timing adjuster

(57) A control apparatus (30) controls supply of working fluid to advancing chambers (51-54) and retarding chambers (55-58). The control apparatus (30) alternately and repeatedly implements an advancing supply period, during which the working fluid is supplied to the advancing chambers (51-54), and a retarding supply period, during which the working fluid is supplied to the retarding chambers (55-58), at time of limiting a phase of a camshaft (2) relative to a crankshaft within a target phase range.

FIG. 1



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Description

[0001] The present invention relates to a valve timing adjuster, which adjusts opening and closing timing (hereinafter, simply referred to as valve timing) of at least one of an intake valve and an exhaust valve of an internal combustion engine.

[0002] For example, a previously known valve timing adjuster includes a housing and a vane rotor. The housing serves as a first rotatable body and is rotated together with a drive shaft, and the vane rotor serves as a second rotatable body and is rotated together with a driven shaft. In the valve timing adjuster, advancing chambers and retarding chambers are arranged one after another in the rotational direction. Each of the advancing chambers and the retarding chambers is formed between a corresponding one of shoes of the housing and a corresponding one of vanes of the vane rotor. Working fluid is supplied to the advancing chambers or the retarding chambers to drive the driven shaft relative to the drive shaft in an advancing direction or a retarding direction to adjust the valve timing.

[0003] In such a valve timing adjuster, as recited in, for example, Japanese Unexamined Patent Publication No. 2006-63835, a variable torque is applied to the driven shaft in response to the rotation of the internal combustion engine. The variable torque is a torque that periodically varies, i.e., changes in an advancing direction for advancing the driven shaft or in a retarding direction for retarding the driven shaft in response to the rotation of the internal combustion engine. Here, the variable torque is caused by, for example, a spring reaction force of each corresponding valve, which is opened and closed by the driven shaft. Also, in a case where a mechanical pump is driven by the driven shaft, the variable torque is generated by a drive reaction force of the mechanical pump. In the valve timing adjuster, in which the variable torque is transmitted through the driven shaft, the phase of the driven shaft (hereinafter, referred to as an engine phase) relative to the drive shaft is set when the torques applied to the driven shaft are balanced. Besides the above-described variable torque, these torques also include a rotational torque, which is generated by supply of the fluid to the advancing chambers and the retarding chambers, and an urging torque, which is generated in a case where a spring is provided to urge the driven shaft.

[0004] When a solenoid spool valve, which is used to control the supply of the fluid to the advancing chambers and the retarding chambers, is controlled in the manner described in Japanese Unexamined Patent Publication No. 2006-63835, the engine phase can be limited within a target phase range to substantially hold the valve timing. Here, when an average value (average torque) of the variable torque is balanced with the other torque (e.g., the urging torque) or becomes substantially zero (for example, in a case where a bearing friction of the driven shaft is substantially zero), the supply of the fluid to both of the advancing chambers and the retarding chambers from the solenoid spool valve may be stopped to make the rotational torque applied to the driven shaft to zero. In this way, the engine phase can be limited within the target phase range. However, in such a case, when the variable torque reaches, for example, its peak torque and thereby becomes large, the advancing chambers or the retarding chambers may possibly be compressed to cause outflow of the working fluid from the advancing chambers or the retarding chambers. This may possibly cause fluctuating movement (repeated forward and backward rotation often referred to as oscillating rotational movement) of the vane rotor relative to the housing. This kind of the fluctuating movement may make it difficult to keep the engine phase within the target phase range for appropriately adjusting the valve timing, which is appropriate for the internal combustion engine. Also, it may cause generation of the hammering sound, which would be generated by hitting movement of the vane rotor against the housing. Thus, such fluctuating movement is not desirable.

[0005] The present invention addresses the above disadvantages. Thus, it is an objective of the present invention to provide a valve timing adjuster, which enables adjustment of valve timing in a more appropriate manner for an internal combustion engine, and which limits generation of hammering sound.

[0006] To achieve the objective of the present invention, there is provided a valve timing adjuster that adjusts opening and closing timing of at least one of an intake valve and an exhaust valve of an internal combustion engine and is placed in a drive force transmission system, which transmits a drive force from a drive shaft of the internal combustion engine to a driven shaft that drives the at least one of the intake valve and the exhaust valve to open and close the same. The valve timing adjuster includes a first rotatable body, a second rotatable body and a supply control means. The first rotatable body is rotated together with the drive shaft. The second rotatable body is rotated together with the driven shaft. The second rotatable body cooperates with the first rotatable body to form an advancing chamber and a retarding chamber, which are arranged one after another in a rotational direction between the first rotatable body and the second rotatable body, and the second rotatable body drives the driven shaft in an advancing direction or a retarding direction relative to the drive shaft upon supplying of working fluid to the advancing chamber or the retarding chamber. The supply control means is for controlling supply of the working fluid to the advancing chamber and the retarding chamber. The supply control means alternately and repeatedly implements an advancing supply period, during which the working fluid is supplied to the advancing chamber, and a retarding supply period, during which the working fluid is supplied to the retarding chamber, at time of limiting a phase of the driven shaft relative to the drive shaft within a target phase range.

[0007] The invention, together with additional objectives, features and advantages thereof, will be best understood from the following description, the appended claims and the accompanying drawings in which:

FIG. 1 is a schematic diagram showing a structure of a valve timing adjuster having a drive apparatus viewed along line I-I in FIG. 2 according to a first embodiment of the present invention:
FIG. 2 is a cross sectional view taken along line II-II in FIG. 1;
FIG. 3 is a lateral view of the drive apparatus shown in FIG. 1;
FIG. 4 is a schematic descriptive diagram for describing an operation of a control apparatus of the valve timing adjuster shown in FIG. 1;
FIG. 5 is a schematic descriptive diagram for describing an operation of the control apparatus shown in FIG. 1;
FIG. 6 is another schematic descriptive diagram for describing an operation of the control apparatus shown in FIG. 1;
FIG. 7 is a schematic descriptive diagram for describing a variable torque applied to the drive apparatus shown in FIG. 1;
FIG. 8 is a diagram for describing an average variable torque applied to the drive apparatus of FIG. 1 and an urging torque generated in the drive apparatus;
FIGS. 9A to 9C are diagrams for describing characteristics of the valve timing adjuster of FIG. 1;
FIGS. 10A to 10C are diagrams for describing the characteristics of the valve timing adjuster of FIG. 1;
FIGS. 11A to 11C are diagrams for describing the characteristics of the valve timing adjuster of FIG. 1;
FIG. 12 is a diagram for describing characteristics of a valve timing adjuster according to a second embodiment of the present invention;
FIG. 13 is a diagram for describing characteristics of a valve timing adjuster according to a third embodiment of the present invention;
FIG. 14 is a diagram for describing the characteristics of the valve timing adjuster according to the third embodiment; and
FIGS. 15A and 15B are diagrams for describing characteristics of a valve timing adjuster according to a fourth embodiment of the present invention.

[0008] Embodiments of the present invention will be described with reference to the accompanying drawings. In the following respective embodiments, similar components will be indicated by the same reference numerals.

(First Embodiment)

[0009] FIGS. 1 to 3 show a valve timing adjuster 1 of a first embodiment of the present invention implemented in an internal combustion engine of a vehicle. The valve timing adjuster 1 is of a hydraulically controlled type, which uses hydraulic oil as working fluid and which adjusts the valve timing of exhaust valves. The valve timing adjuster 1 includes a drive apparatus 10 and a control apparatus 30. The drive apparatus 10 is hydraulically driven in a drive force transmission system, which transmits a drive force of an undepicted crankshaft (serving as a drive shaft) of the internal combustion engine to a camshaft 2 (serving as a driven shaft) of the internal combustion engine. The control apparatus 30 serves as a supply control means and controls supply of oil to the drive apparatus 10. A mechanical fuel injection pump (not shown) of the internal combustion engine is connected to the camshaft 2, which drives the exhaust valves to open and close the same. The fuel injection pump is driven in response to the rotation of the camshaft 2.

[0010] First, the drive apparatus 10 will be described. A housing (serving as a first rotatable body) 18 of the drive apparatus 10 includes a sprocket 11, a shoe housing 12 and a front plate 13.

[0011] The shoe housing 12 is configured into a cylindrical body and includes a plurality of shoes 12a-12d, which are placed at generally equal intervals in the rotational direction. Each shoe 12a-12d projects radially inward and serves as a partition. A projecting end surface of each shoe 12a-12d forms an arcuate surface when it is viewed in a direction perpendicular to the plane of FIG. 2. The projecting end surface of each shoe 12a-12d slidably engages an outer peripheral wall surface of a boss 14a of a vane rotor 14. A seal member 15 is fitted into a recess, which is provided in the projecting end surface of each shoe 12a-12d. A receiving chamber 50 is formed between each adjacent two of the shoes 12a-12d, which are adjacent to each other in the rotational direction. Each receiving chamber 50 is defined by lateral surfaces of the corresponding shoes 12a-12d and an inner peripheral wall surface of the shoe housing 12 and has a fan shape as viewed in the direction perpendicular to the plane of FIG. 2.

[0012] The sprocket 11 is configured into a cylindrical tubular body, and the front plate 13 is configured into an annular plate body. The shoe housing 12 is coaxially clamped between the sprocket 11 and the front plate 13, and the sprocket 11, the shoe housing 12 and the front plate 13 are fixed together with bolts. The sprocket 11 is connected to the crankshaft through a timing chain (not shown). In this way, the housing 18 is rotated together with the crankshaft when the drive force is transmitted from the crankshaft to the sprocket 11 upon the operation of the internal combustion engine. At this time, the housing 18 is rotated in a clockwise direction in FIGS. 2 and 3.

[0013] The vane rotor 14, which serves as a second rotatable body, is received in the housing 18. Two opposed axial end surfaces of the vane rotor 14 are slidably engaged with an inner surface of the sprocket 11 and an inner surface of the front plate 13, respectively. The vane rotor 14 includes the cylindrical boss 14a and a plurality of vanes 14b-14e.

[0014] A cylindrical tubular bush 20 is relatively rotatably received at a location radially inward of the front plate 13 and is coaxially engaged with one end portion of the boss 14a. The boss 14a is fixed together with the bush 20 to the camshaft 2, which is coaxial with the boss 14a, with a bolt. Thus, the vane rotor 14 is rotated together with the camshaft 2 and the bush 20 in the clockwise direction in FIGS. 2 and 3. Furthermore, the vane rotor 14 and the camshaft 2 are rotatable relative to the housing 18. In FIGS. 2 and 3, a direction of an arrow X indicates an advancing direction (a direction toward an advancing side) of the vane rotor 14 relative to the housing 18, and a direction of an arrow Y indicates a retarding direction (a direction toward a retarding side) of the vane rotor 14 relative to the housing 18.

[0015] An assist spring 22 is a torsion coil spring and serves as a resilient member. The assist spring 22 is placed radially inward of the bush 20. One end portion of the assist spring 22 is anchored to the housing 18 through an anchoring pin 18a, and the other end portion of the assist spring 22 is anchored to an anchoring groove 14f, which is formed in the boss 14a of the vane rotor 14. A restoring force, which is generated by the assist spring 22, serves as an urging torque Ts that urges the vane rotor 14 in the advancing direction X relative to the housing 18.

[0016] The vanes 14b-14e, which are placed one after another at the generally equal intervals in the rotational direction at the boss 14a, radially outwardly project from the boss 14a and are received in the receiving chambers 50, respectively. A projecting end surface of each vane 14b-14e forms an arcuate surface as viewed in the direction perpendicular to the plane of FIG. 2 and is slidably engaged with the inner peripheral wall surface of the shoe housing 12. A seal member 16 is fitted into a recess, which is provided in the projecting end surface of each vane 14b-14e.

[0017] Each vane 14b-14e divides the corresponding receiving chamber 50 to form an advancing chamber and a retarding chamber relative to the housing 18. Specifically, the advancing chamber 51 is formed between the shoe 12a and the vane 14b, and the advancing chamber 52 is formed between the shoe 12b and the vane 14c. Furthermore, the advancing chamber 53 is formed between the shoe 12c and the vane 14d, and the advancing chamber 54 is formed between the shoe 12d and the vane 14e. Also, the retarding chamber 55 is formed between the shoe 12d and the vane 14b, and the retarding chamber 56 is formed between the shoe 12a and the vane 14c. Also, the retarding chamber 57 is formed between the shoe 12b and the vane 14d, and the retarding chamber 58 is formed between the shoe 12c and the vane 14c.

[0018] Therefore, when the vane rotor 14 is placed in a most advanced position in the advancing direction X with respect to the housing 18, a volume of each advancing chamber 51-54 is maximized while a volume of each retarding chamber 55-58 is minimized. In contrast, when the vane rotor 14 is placed in a most retarded position in the retarding direction Y with respect to the housing 18, the volume of each retarding chamber 55-58 is maximized while the volume of each advancing chamber 51-54 is minimized.

[0019] The advancing chambers 51-54 are communicated with advancing passages 61-64, which are formed in the sprocket 11 and are communicated with an advancing passage 71 formed in the camshaft 2. The retarding chambers 55-58 are communicated with retarding passages 65-68, which are formed in the vane rotor 14, and the retarding passages 65-68 are communicated with a retarding passage 72 formed in the camshaft 2.

[0020] A stopper pin 26 is received in the vane 14b. When the stopper pin 26 is urged by the restoring force of a compression coil spring 28 and is thereby fitted into an engaging ring 27 of the sprocket 11, the vane rotor 14 is arrested in the most advanced position, which is most advanced in the advancing direction X relative to the housing 18. When the stopper pin 26 receives the pressure of the oil supplied from the retarding chamber 55 through a passage 29 formed in the sprocket 11, the stopper pin 26 is axially displaced from the engaging ring 27. Therefore, the rotation of the vane rotor 14 relative to the housing 18 is enabled, i.e., is permitted.

[0021] Next, the control apparatus 30 will be described. In the control apparatus 30, the advancing passage 73 and the retarding passage 74 are communicated with the advancing passage 71 and the retarding passage 72, respectively, of the camshaft 2.

[0022] A switch control valve 31 is communicated with the advancing passage 73, the retarding passage 74, a pump passage 75 and drain passages 76, 77. An oil pump (serving as a fluid supply source) 4 is provided in the pump passage 75. The oil pump 4 draws the oil from the oil tank 5 through an upstream side part of the pump passage 75 and discharges the oil toward the switch control valve 31 through a downstream side part of the pump passage 75. The oil pump 4 of the present embodiment is a mechanical pump that is driven by the crankshaft. The drain passages 76, 77 are provided to enable draining of the oil from the switch control valve 31 toward the oil tank 5.

[0023] The switch control valve 31 is a solenoid spool valve that axially drives the spool 34 in response to a balance between the drive force, which is generated by a solenoid drive arrangement 32 upon energization thereof, and a restoring force, which is generated by the return spring 33 in a direction opposite from the direction of the drive force. The switch control valve 31, which is connected with the passages 73-77, switches the communication of the pump passage 75 and the drain passages 76, 77 to the advancing passage 73 and the retarding passage 74.

[0024] Specifically, when the drive current, which is supplied to the solenoid drive arrangement 32, is smaller than a reference value Ib, the advancing passage 73 is communicated with the pump passage 75, so that the oil discharged from the oil pump 4 is supplied to the advancing passage 73 through the pump passage 75, as shown in FIG. 4. At this time, as shown in FIG. 4, the retarding passage 74 is communicated with the drain passage 76, and the oil of the retarding passage 74 is drained to the oil tank 5 through the drain passage 76.

[0025] When the drive current, which is supplied to the solenoid drive arrangement 32, is larger than the reference value Ib, the retarding passage 74 is communicated with the pump passage 75, so that the oil discharged from the oil pump 4 is supplied to the retarding passage 74 through the pump passage 75, as shown in FIG. 5. At this time, as shown in FIG. 5, the advancing passage 73 is communicated with the drain passage 77, and the oil of the advancing passage 73 is drained to the oil tank 5 through the drain passage 77.

[0026] When the drive current, which is supplied to the solenoid drive arrangement 32, is equal to the reference value Ib, the communication of each of the advancing passage 73 and the retarding passage 74 to the pump passage 75 and the drain passages 76, 77 is interrupted, as shown in FIG. 6. Therefore, the oil, which is discharged from the oil pump 4, is not supplied to the advancing passage 73 and the retarding passage 74, and the oil in the advancing passage 73 and the oil in the retarding passage 74 remain therein.

[0027] A control circuit 36 of the control apparatus 30 shown in FIG. 1 includes a microcomputer, which has a memory 36a. The control circuit 36 controls electric power supply to the switch control valve 31 and also controls the operation of the internal combustion engine. Specifically, besides the switch control valve 31, a plurality of sensors, which includes a cam angle sensor 7 and a crank angle sensor 8, is electrically connected to the control circuit 36. The control circuit 36 computes an actual phase and a target phase of the camshaft 2 relative to the crankshaft based on an output of each corresponding sensor. Based on the computed result, the control circuit 36 controls the power supply to the switch control valve 31, i.e., controls the drive current supplied to the switch control valve 31. The cam angle sensor 7 is placed, for example, adjacent to the camshaft 2 to sense a rotational angle of the camshaft 2. The crank angle sensor 8 is placed, for example, adjacent to the crankshaft and senses a rotational angle of the crankshaft.

[0028] The drive apparatus 10 and the control apparatus 30 of the valve timing adjuster have been described. Now, the variable torque, which is applied to the drive apparatus 10, will be described.

[0029] During the operation of the internal combustion engine, the variable torque (i.e., the torque that varies with time, more specifically, oscillates with time) is applied to the camshaft 2 and the vane rotor 14 in response to a spring reaction force from each corresponding exhaust valve driven to open and close by the camshaft 2 and the drive reaction force of the fuel injection pump, which is driven by the camshaft 2. Here, as shown in FIG. 7, the variable torque periodically changes between a positive torque, which acts in a direction for retarding the engine phase of the camshaft 2 relative to the crankshaft, and a negative torque, which acts in a direction for advancing the engine phase. In FIG. 7 as well as other drawings, the retarding is abbreviated as "RTD", and the advancing is abbreviated as "ADV". The variable torque of the present invention is such that a peak torque Tc+ of the positive torque is larger than a peak torque Tc- of the negative torque due to the friction between the camshaft 2 and a journal (not shown) for supporting the camshaft 2. Therefore, an average torque (hereinafter, referred to as an average variable torque) Tca of the variable torque is biased on the positive torque side, which is opposite from the urging torque Ts of the assist spring 22, i.e., on the retarding side Y Furthermore, as shown in FIG. 8, when the rotational speed (i.e., the number of revolutions per unit time) of the internal combustion engine is increased, the average torque Tca is increased.

[0030] Now, the variable torque, which is applied to the drive apparatus 10, will be described. Hereinafter, the characteristic operation of the valve timing adjuster 1 will be described.

[0031] In a stop state of the internal combustion engine, the stopper pin 26 is fitted into the engaging ring 27 by the restoring force of the compression coil spring 28. When the internal combustion engine is started from the stop state, the oil pump 4 is driven, and the retarding passage 74 is communicated with the pump passage 75 by controlling the drive current, which is applied from the control circuit 36 to the switch control valve 31, to a value that is larger than the reference value Ib. Then, the oil, which is discharged from the oil pump 4, is supplied to the respective retarding chambers 55-58 through the pump passage 75 and the retarding passages 74, 72, 65-68. Therefore, the stopper pin 26 receives the oil pressure from the retarding chamber 55 through the passage 29, so that the stopper pin 26 is removed, i.e., is dislodged from the engaging ring 27 against the restoring force of the compression coil spring 28 upon increasing the oil pressure, which is received from the retarding chamber 55, to the predetermined value. Therefore, the vane rotor 14 is placed into the rotatable state where the vane rotor 14 is rotatable relative to the housing 18.

[0032] Thereafter, the control circuit 36 controls the electric power supply to the switch control valve 31 to change each communicating one of the pump passage 75 and the drain passages 76, 77, which is communicated with the corresponding one of the advancing passage 73 and the retarding passage 74, thereby adjusting the valve timing. Now, the valve timing control operation will be described in detail.

[0033] First, the valve timing advancing operation for advancing the valve timing will be described. In the case where the accelerator of the internal combustion engine is in an off state or in the case where a predetermined operational condition, which indicates a low/middle speed high load operational state of the internal combustion engine that requires the output torque, is satisfied, the control circuit 36 controls the drive current supplied to the switch control valve 31 to a value smaller than the reference value Ib. In this way, the advancing passage 73 is communicated with the pump passage 75, and the retarding passage 74 is communicated with the drain passage 76. Therefore, the oil discharged from the oil pump 4 is supplied to the respective advancing chambers 51-54 through the pump passage 75 and the advancing passages 73, 71, 61-64. Furthermore, at this time, the oil in the respective retarding chambers 55-58 is drained to the oil tank 5 through the retarding passages 65-68, 72, 74 and the drain passage 76. In this way, the pressure of the oil is applied to the vanes 14b-14e, which face the advancing chambers 51-54, respectively, thereby generating the rotational torque Tv, which drives the vane rotor 14 to rotate the same relative to the housing 18 in the advancing direction X. As a result, the engine phase of the camshaft 2 relative to the crankshaft and thereby the valve timing is advanced.

[0034] Next, the valve timing retarding operation for retarding the valve timing will be described. In the case where a predetermined operational condition, which indicates a normal operational state where the internal combustion engine is driven with a light load, is satisfied, the control circuit 36 controls the drive current supplied to the switch control valve 31 to a value larger than the reference value Ib. Thereby, the retarding passage 74 is communicated with the pump passage 75, and the advancing passage 73 is communicated with the drain passage 77. Thus, the oil, which is discharged from the oil pump 4, is supplied to the respective retarding chambers 55-58 through the pump passage 75 and the retarding passages 74, 72, 65-68. Furthermore, at this time, the oil in the respective advancing chambers 51-54 is drained to the oil tank 5 through the advancing passages 61-64, 71, 73 and the drain passage 77. In this way, the pressure of the oil is applied to the vanes 14b-14e, which face the retarding chambers 55-58, respectively, thereby generating the rotational torque Tv, which drives the vane rotor 14 to rotate the same relative to the housing 18 in the retarding direction Y As a result, the engine phase of the camshaft 2 relative to the crankshaft and thereby the valve timing is retarded.

[0035] Next, the valve timing holding operation for substantially holding the valve timing will be described. In the case where a predetermined operational condition (hereinafter, a stable operational condition), which indicates a stable operational state (e.g., a holding state of the accelerator or accelerator pedal) of the internal combustion engine, is satisfied as a limiting condition, the control circuit 36 controls the drive current supplied to the switch control valve 31 to supply the oil to the respective advancing chambers 51-54 like in the case of the advancing operation described above. Thereby, the rotational torque Tv in the advancing direction X against the average variable torque Tca is generated. At this time, the control circuit 36 computes an actual phase Pr based on the output of the cam angle sensor 7 and the output of the crank angle sensor 8 with respect to the engine phase of the camshaft 2 relative to the crankshaft. Thereby, the control circuit 36 adjusts the drive current supplied to the switch control valve 31 within a range lower than the reference value Ib to limit the actual phase Pr within a predetermined target phase range ΔPt. Therefore, the current valve timing is substantially held.

[0036] When the valve timing is substantially held in the above described manner, the average variable torque Tca may possibly be balanced with the urging torque Ts of the assist spring 22, as indicated with a shaded circle in FIG. 8. Therefore, in such a case, even when the drive current supplied to the switch control valve 31 is adjusted, this adjustment is made within the range lower than the reference value Ib. Thereby, the supply of the oil to the respective advancing chambers 51, 54 is maintained. As a result, the actual phase Pr reaches an advancing end of the target phase range ΔPt, which is opposite from a bias of the average variable torque Tc. Thus, in this case, similar to the above case of retarding operation, the control circuit 36 controls the drive current supplied to the switch control valve 31 to supply the oil to the respective retarding chambers 55, 58 to return the actual phase Pr to an intermediate phase (a phase intermediate between the advancing end and the retarding end) within the target phase range ΔPt, and thereafter the control circuit 36 executes an alternately repeating supply operation.

[0037] Specifically, in the alternately repeating supply operation, as indicated in FIGS. 9B, 10B and 11B, an advancing (ADV) supply period and a retarding (RTD) supply period are alternately repeatedly implemented. In the advancing supply period (also referred to as an advancing supply process), the oil is supplied to the respective advancing chambers 51-54 by controlling the drive current supplied to the switch control valve 31 in the manner similar to that of the advancing operation discussed above. In the retarding supply period (also referred to as a retarding supply period), the oil is supplied to the respective retarding chambers 55-58 by controlling the drive current supplied to the switch control valve 31 in the manner similar to that of the retarding operation discussed above. At this time, the actual phase Pr is limited within the target phase range ΔPt, so that the holding of the valve timing is maintained.

[0038] Here, in the alternately repeating supply operation of the present embodiment, the supply of the oil to the respective advancing chambers 51-54 is maintained throughout each corresponding advancing supply period, and the supply of the oil to the respective retarding chambers 55-58 is maintained throughout each corresponding retarding supply period. Furthermore, in the alternately repeating supply operation, the period ω of cycle of the change in the variable torque, which corresponds to the current actual rotational speed Nr of the internal combustion engine, is computed based on the correlation information, which indicates the relationship between the rotational speed of the internal combustion engine and the period ω of cycle of the change in the variable torque (see FIG. 7). Then, the advancing supply period and the retarding supply period are alternately repeated in a manner that causes generation of the rotational torque Tv, which shows the cyclic change having the period of cycle that is different from the computed period ω of cycle of the change in the variable torque, as shown in FIGS. 9A, 9C, 10A, 10C, 11A and 11C. At this time, as long as the actual phase Pr does not exceed the target phase range ΔPt, the period of cycle of the change in the rotational torque Tv may be shorter than the period ω of cycle of the change in the variable torque, as shown in FIG. 9C, or may be longer than the period ω of cycle of the change in the variable torque, as shown in FIG. 10C, or may be the same as the period ω of cycle of the change in the variable torque with the reversed phase (advanced or retarded), as shown in FIG. 11C.

[0039] The correlation information, which indicates the relationship between the rotational speed of the internal combustion engine and the period w of cycle of the change in the variable torque, is preset in a form of a map, a table or a mathematical equation according to the specification of the internal combustion engine installed in the vehicle together with the valve timing adjuster 1. The correlation information is stored in the memory 36a of the control circuit 36 and is used to compute the period ω of cycle of the change in the variable torque. Alternatively, the period w of cycle of the change in the variable torque may be learned from the output of the cam angle sensor 7 and the output of the crank angle sensor 8, and the correlation information stored in the memory 36a may be updated regularly based on the result of the learning.

[0040] Furthermore, the holding operation is continued until the stable operational condition, which serves as the limiting condition, is no longer satisfied.

[0041] As described above, even when the average variable torque Tca is balanced with the urging torque Ts at the time of limiting the actual phase Pr within the target phase range ΔPt, the oil is certainly supplied to the advancing chambers 51-54 or the retarding chambers 55-58 by alternately repeating the advancing supply period and the retarding supply period. In this way, even under the influence of the relatively large variable torque, the outflow of the oil from the advancing chambers 51-54 and the retarding chambers 55-58 is well limited. Therefore, the fluctuating movement (oscillating rotational movement) of the vane rotor 14 relative to the housing 18 can be limited without the need for increasing the urging torque Ts of the assist spring 22. Furthermore, the advancing supply period and the retarding supply period are alternately repeated to generate the rotational torque Tv, which shows the cyclic change with the period of cycle that is different from the period ω of cycle of the change in the variable torque. Therefore, the rotational torque Tv acts against the variable torque to effectively limit the fluctuating movement of the vane rotor 14.

[0042] As described above, according to the first embodiment, the actual phase Pr is appropriately limited within the target phase range ΔPt, and the valve timing is adjusted to the appropriate timing, which is appropriate for the internal combustion engine. Furthermore, the hammering sound, which is caused by the collision between the housing 18 and the vane rotor 14, can be advantageously limited.

(Second Embodiment)

[0043] A second embodiment of the present invention, which is a modification of the first embodiment, will be described with reference to FIG. 12.

[0044] As shown in FIG. 12, the discharge pressure of the oil at the oil pump 4 driven by the internal combustion engine, i.e., the pressure of the oil supplied to the advancing chambers 51-54 and the retarding chambers 55-58 is increased in response to an increase in the rotational speed of the internal combustion engine. Also, the pressure of the oil changes depending on the environmental temperature.

[0045] In view of the above point, according to the second embodiment, the control circuit 36 returns the actual phase Pr to an intermediate phase (a phase intermediate between the advancing end and the retarding end) in the target phase range ΔPt and then executes the alternately repeating supply operation, which is similar to that of the first embodiment, in the case where the actual phase Pr reaches the advancing end of the target phase range ΔPt, and the pressure of the oil becomes equal to or less than a preset value S during the execution of the normal holding operation (hereinafter, simply referred to as "normal holding operation") for substantially holding the valve timing by adjusting the drive current supplied to the switch control valve 31 within the range lower than the reference value Ib. Thereby, in the low oil pressure state where the pressure of the oil is equal to or less than the preset value S, it is possible to reliably limit the fluctuating movement of the vane rotor 14, which tends to occur in the low oil pressure state.

[0046] Even in the case where the actual phase Pr reaches the advancing end of the target phase range ΔPt during the normal holding operation, as long as the pressure of the oil is larger than the preset value S (e.g., about 250 kPa), the possibility of the fluctuating movement of the vane rotor 14 is reduced in comparison to the case where the pressure of the oil is equal to or less than the preset value S. Therefore, in such a case, according to the present embodiment, the normal holding operation is maintained without executing the alternately repeating supply operation.

(Third Embodiment)

[0047] A third embodiment of the present invention, which is a modification of the first embodiment, will be described with reference to FIGS. 13 and 14. As shown in FIG. 13, the urging torque Ts of the assist spring 22 increases when the relative rotational position of the vane rotor 14 relative to the housing 18 is shifted in the retarding direction Y, i.e., when the engine phase of the camshaft 2 relative to the crankshaft is shifted in the retarding direction Y Furthermore, as discussed in the first embodiment (see FIG. 8), the average variable torque Tc increases when the rotational speed of the internal combustion engine increases. With reference to FIG. 14, for descriptive purpose, it is now defined that a reference rotational speed Nb of the internal combustion engine is a rotational speed, at which the average variable torque Tca coincides with a minimum value Tsmin of the urging torque Ts. Then, when the actual rotational speed Nr of the internal combustion engine becomes equal to or higher than this reference rotational speed Nb, the average variable torque Tc may possibly be balanced with the urging torque Ts.

[0048] Therefore, according to the third embodiment, in the case where the actual rotational speed Nr becomes equal to or higher than the reference rotational speed Nb during the normal holding operation, the control circuit 36 executes the alternately repeating supply operation, which is similar to that of the first embodiment. In this way, in the case where the average variable torque Tca is balanced with the urging torque Ts, it is possible to reliably limit the fluctuating movement of the vane rotor 14 by the alternately repeating supply operation.

[0049] In contrast, in the case where the actual rotational speed Nr is less than the reference rotational seed Nb, the average variable torque Tca is less likely balanced with the urging torque Ts. Therefore, in such a case, according to the present embodiment, the normal holding operation is maintained without executing the alternately repeating supply operation.

(Fourth Embodiment)

[0050] A fourth embodiment of the present invention, which is a modification of the first embodiment, will be described with reference to FIGS. 15A and 15B. In the fourth embodiment, as shown in FIGS. 15A and 15B, the control circuit 36 starts the alternately repeating supply operation, which is similar to that of the first embodiment, upon satisfaction of the stable operational condition, which serves as the limiting condition. Then, when the stable operational condition is no longer satisfied, the control circuit 36 terminates the alternately repeating supply operation. Specifically, according to the present embodiment, the alternately repeating supply operation is maintained while the actual phase Pr is limited within the target phase range ΔPt upon the satisfaction of the stable condition. Thus, according to the fourth embodiment, even when the average variable torque Tca is balanced with the urging torque Ts of the assist spring 22, the fluctuating movement of the vane rotor 14 can be reliably limited by the alternately repeating supply operation.

[0051] The present invention has been described with respect to the above embodiments. However, the present invention is not limited to the above embodiments, and the above embodiments may be modified within a spirit and scope of the present invention.

[0052] For example, a bearing may be interposed between the camshaft 2 and the journal thereof to substantially eliminate the friction between the camshaft 2 and the journal, and the assist spring 22 may be eliminated. Even with this construction, the fluctuating movement of the vane rotor 14 can be limited by the holding operation, which maintains the alternately repeating supply operation like in the fourth embodiment.

[0053] Furthermore, in the first to fourth embodiments, the supply of the oil to the respective advancing chambers 51-54 may be intermittently performed in the advancing supply period. In other words, it is not necessary to maintain the supply of the oil to the respective advancing chambers 51-54 throughout each advancing supply period, and the supply of the oil to the respective advancing chambers 51-54 may be stopped before the end of the advancing supply period, if desired. Similarly, in the first to fourth embodiments, the supply of the oil to the retarding chambers 55-58 may be intermittently performed in the retarding supply period. In other words, it is not necessary to maintain the supply of the oil to the respective retarding chambers 55-58 throughout each advancing supply period, and the supply of the oil to the respective retarding chambers 55-58 may be stopped before the end of the retarding supply period, if desired.

[0054] Furthermore, in the first embodiment, when the actual phase Pr reaches the advancing end of the target phase range ΔPt during the normal holding operation, the alternately repeating supply operation, which is similar to that of the first embodiment, may be started immediately from the beginning of the retarding supply period. Furthermore, in the second embodiment, when the actual phase Pr reaches the advancing end of the target phase range ΔPt during the normal holding operation, and the pressure of the oil becomes equal to or less than the preset value S, the alternately repeating supply operation, which is similar to that of the first embodiment, may be started immediately from the beginning of the retarding supply period.

[0055] Furthermore, in the third embodiment, like in the second embodiment, when the actual rotational speed Nr of the internal combustion engine becomes equal to or larger than the reference rotational speed Nb during the normal holding operation, and the pressure of the oil becomes equal to or less than the preset value S, the alternately repeating supply operation, which is similar to that of the first embodiment, may be executed. Similarly, in the fourth embodiment, the normal holding operation may be started upon satisfaction of the stable condition, which serves as the limiting condition. Then, when the pressure of the oil becomes equal to or less than the preset value S during the normal holding operation, the alternately repeating supply operation, which is similar to that of the first embodiment, may be executed.

[0056] In addition, in the first to fourth embodiments, the housing 18 is rotated together with the crankshaft, and the vane rotor 14 is rotated together with the camshaft 2. However, the present invention is also applicable to a valve timing adjuster, in which the vane rotor 14 is rotated together with the crankshaft, and the housing 18 is rotated together with the camshaft 2.

[0057] Furthermore, in the first to fourth embodiments, the present invention is applied to the valve timing adjuster, which controls the valve timing of the exhaust valves. Alternatively, the present invention may be applied to a system, which controls valve timing of intake valves, or a system, which controls the valve timing of both of the intake valves and the exhaust valves.

[0058] Additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader terms is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described.

[0059] A control apparatus (30) controls supply of working fluid to advancing chambers (51-54) and retarding chambers (55-58). The control apparatus (30) alternately and repeatedly implements an advancing supply period, during which the working fluid is supplied to the advancing chambers (51-54), and a retarding supply period, during which the working fluid is supplied to the retarding chambers (55-58), at time of limiting a phase of a camshaft (2) relative to a crankshaft within a target phase range.

Claims

1. A valve timing adjuster that adjusts opening and closing timing of at least one of an intake valve and an exhaust valve of an internal combustion engine and is placed in a drive force transmission system, which transmits a drive force from a drive shaft of the internal combustion engine to a driven shaft (2) that drives the at least one of the intake valve and the exhaust valve to open and close the same, the valve timing adjuster comprising:

    a first rotatable body (18) that is rotated together with the drive shaft;
    a second rotatable body (14) that is rotated together with the driven shaft (2), wherein the second rotatable body (14) cooperates with the first rotatable body (18) to form an advancing chamber (51-54) and a retarding chamber (55-58), which are arranged one after another in a rotational direction between the first rotatable body (18) and the second rotatable body (14), and the second rotatable body (14) drives the driven shaft (2) in an advancing direction or a retarding direction relative to the drive shaft upon supplying of working fluid to the advancing chamber (51-54) or the retarding chamber (55-58); and
    a supply control means (30) for controlling supply of the working fluid to the advancing chamber (51-54) and the retarding chamber (55-58), wherein the supply control means (30) alternately and repeatedly implements an advancing supply period, during which the working fluid is supplied to the advancing chamber (51-54), and a retarding supply period, during which the working fluid is supplied to the retarding chamber (55-58), at time of limiting a phase of the driven shaft (2) relative to the drive shaft within a target phase range.

2. The valve timing adjuster according to claim 1, further comprising a resilient member (22) that generates an urging torque to urge the driven shaft (2) in a direction that is opposite from a direction of an average torque of a variable torque, which changes with time and is applied to the driven shaft (2).

3. The valve timing adjuster according to claim 2, wherein the supply control means (30) alternately and repeatedly implements the advancing supply period and the retarding supply period in a case where an actual phase of the driven shaft (2) relative to the drive shaft reaches a corresponding one of an advancing end and a retarding end of the target phase range, which is opposite from the direction of the average torque upon satisfaction of a limiting condition for limiting the phase of the driven shaft (2) relative to the drive shaft within the target phase range.

4. The valve timing adjuster according to claim 3, wherein the supply control means (30) alternately and repeatedly implements the advancing supply period and the retarding supply period after the supply control means (30) returns the actual phase to an intermediate phase in the target phase range in the case where the actual phase reaches the corresponding one of the advancing end and the retarding end of the target phase range, which is opposite from the direction of the average torque, upon the satisfaction of the limiting condition for limiting the phase of the driven shaft (2) relative to the drive shaft within the target phase range.

5. The valve timing adjuster according to claim 2, wherein:

    the supply control means (30) alternately and repeatedly implements the advancing supply period and the retarding supply period in a case where an actual rotational speed of the internal combustion engine becomes equal to or larger than a reference rotational speed of the internal combustion engine upon satisfaction of a limiting condition for limiting the phase of the driven shaft (2) relative to the drive shaft within the target phase range; and
    the reference rotational speed of the internal

combustion engine is defined as a rotational speed of the internal combustion engine, at which the average torque that increases as the rotational speed of the internal combustion engine increases generally coincides with a minimum value of the urging torque.

6. The valve timing adjuster according to claim 1 or 2, wherein the supply control means (30) maintains the alternately and repeatedly implementing of the advancing supply period and the retarding supply period as long as the supply control means (30) limits the phase of the driven shaft (2) relative to the drive shaft within the target phase range.

7. The valve timing adjuster according to any one of claims 1 to 6, wherein:

a rotational torque, which drives the driven shaft (2) in an advancing direction or a retarding direction relative to the drive shaft, is generated by the supplying of the working fluid to the advancing chamber (51-54) or the retarding chamber (55-58); and
the supply control means (30) alternately and repeatedly implements the advancing supply period and the retarding supply period such that the rotational torque is generated with a different period of a cycle that is different from a period of a cycle of the variable torque.

8. The valve timing adjuster according to any one of claims 1 to 7, wherein:

a rotational torque, which drives the driven shaft (2) in an advancing direction or a retarding direction relative to the drive shaft, is generated by the supplying of the working fluid to the advancing chamber (51-54) or the retarding chamber (55-58); and
the supply control means (30) alternately and repeatedly implements the advancing supply period and the retarding supply period in a case where a pressure of the working fluid supplied to the advancing chamber (51-54) and the retarding chamber (55-58) becomes equal to or less than a preset value upon satisfaction of a limiting condition for limiting the phase of the driven shaft (2) relative to the drive shaft within a target phase range.

FIG. 1

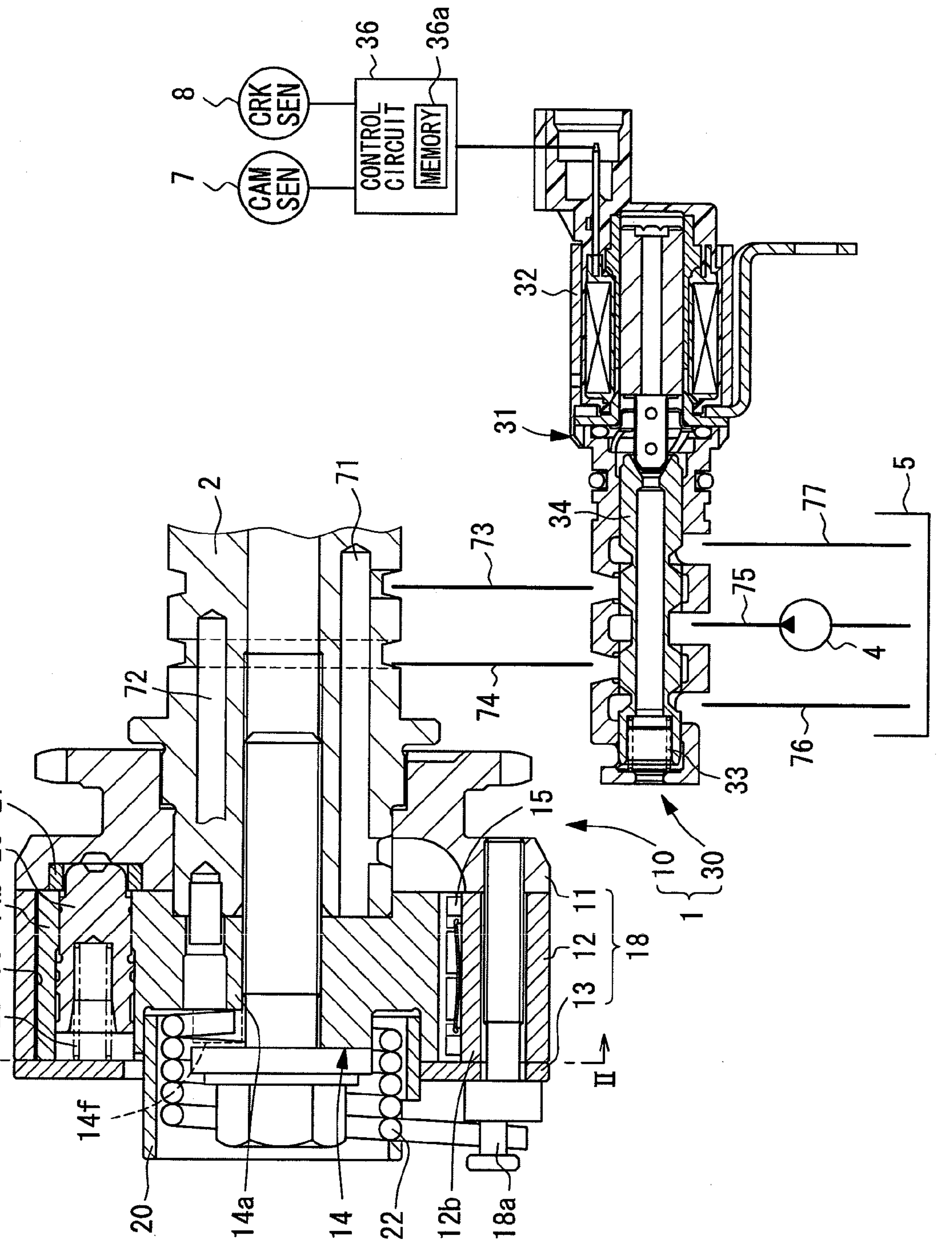

CAM SEN
CRK SEN
CONTROL CIRCUIT
MEMORY
7
8
36
36a
32
31
2
71
73
34
77
5
75
4
72
74
76
33
27
26
14b
50
28
15
10
30
1
11
12
13
18
II
14f
20
14a
14
22
12b
18a

FIG. 2

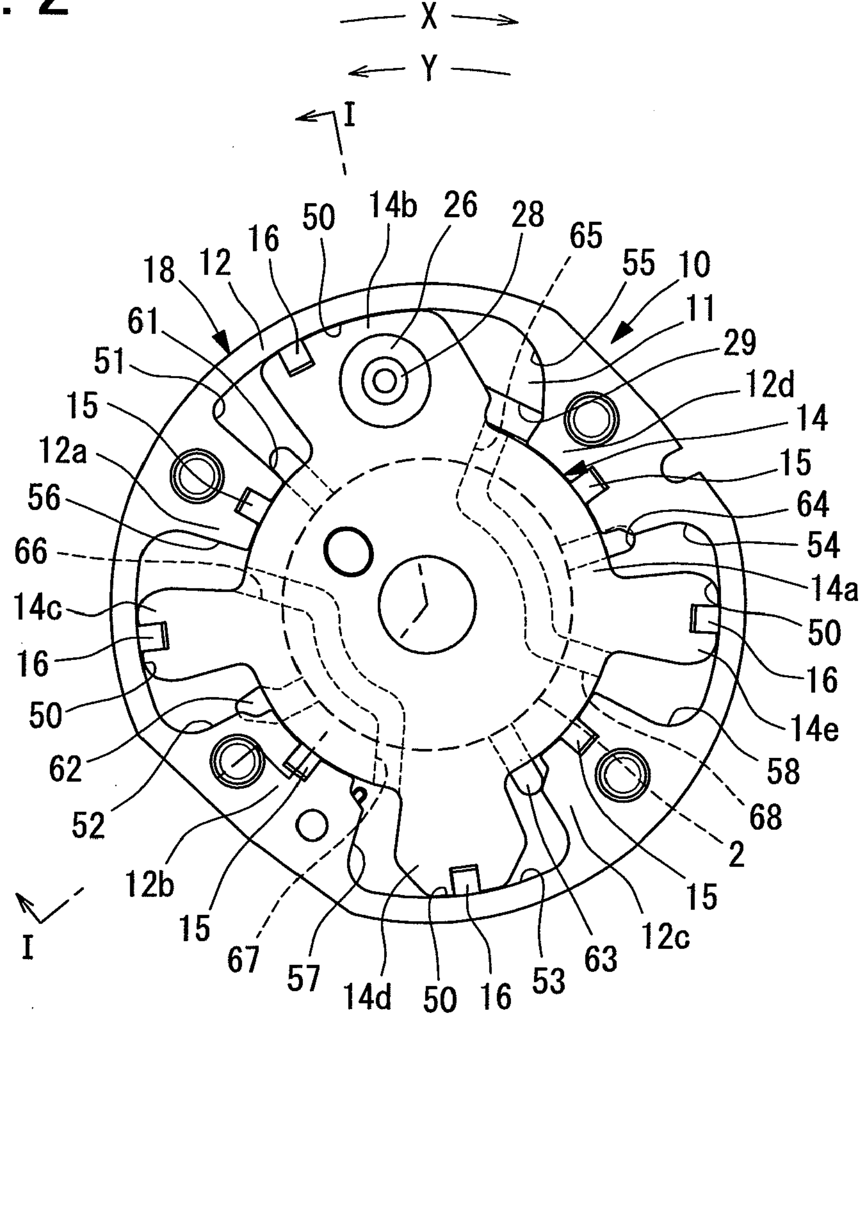

X
Y
I
50
14b
26
28
65
55
10
18
12
16
11
61
29
51
12d
15
14
12a
15
56
64
66
54
14a
14c
50
16
16
50
14e
62
58
68
52
2
12b
15
15
12c
67
57
14d
50
16
53
63
I

FIG. 3

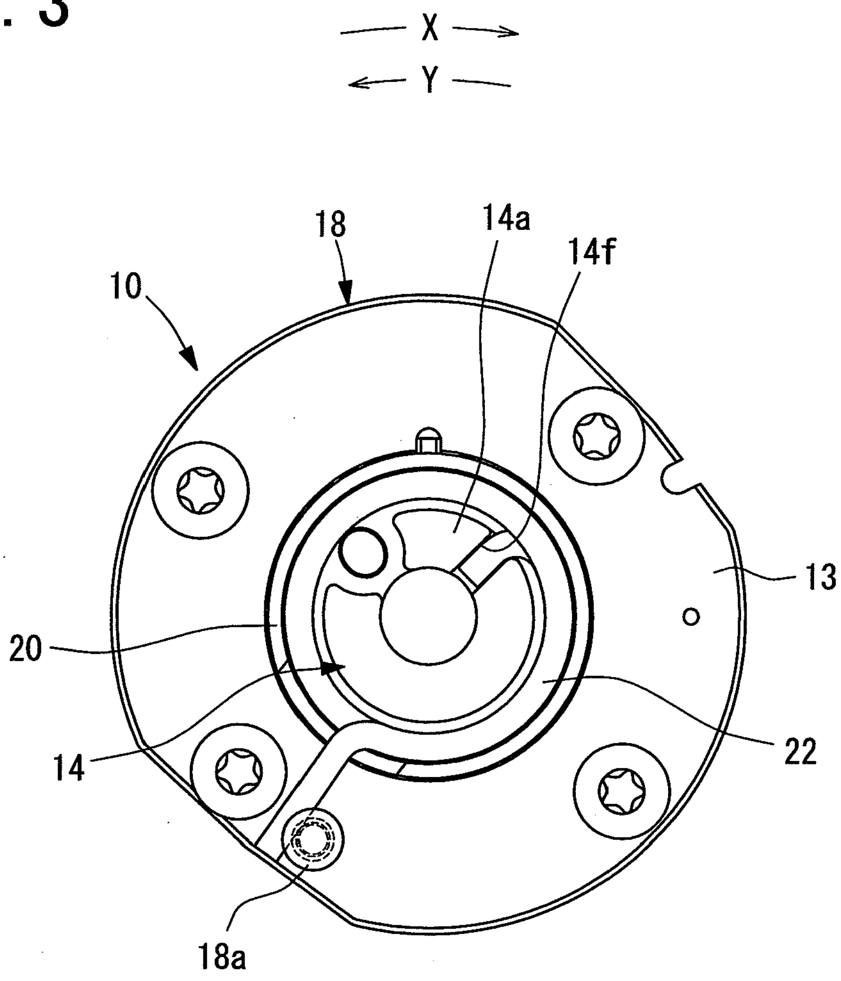


FIG. 4

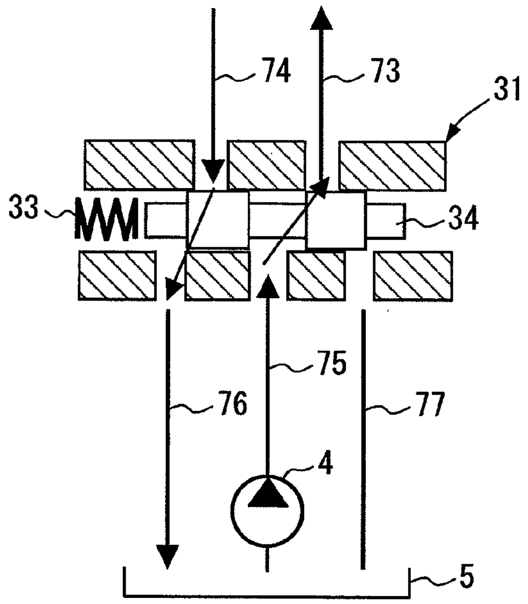


FIG. 5

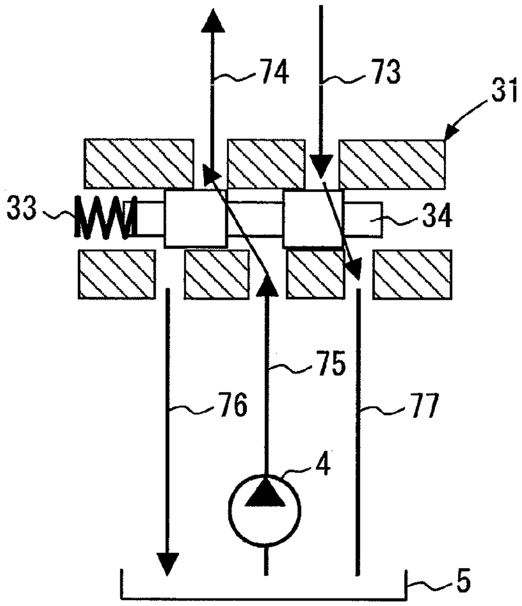


FIG. 6

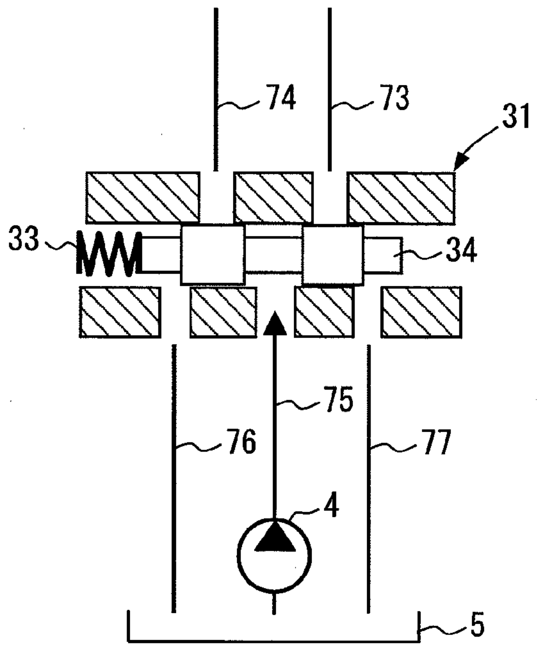

74
73
31
33
34
75
76
77
4
5

FIG. 7

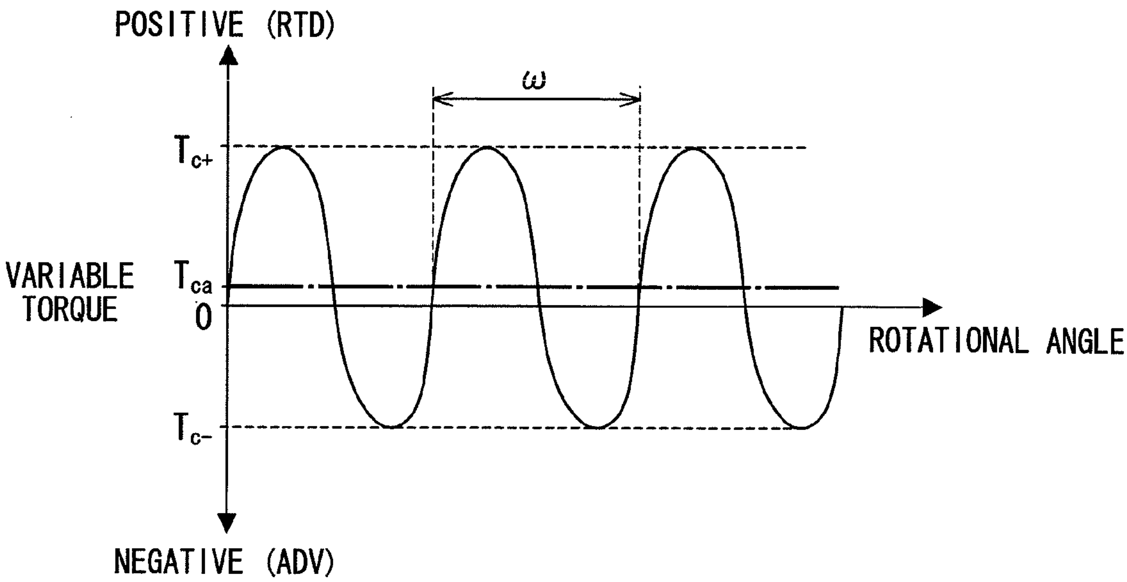

POSITIVE (RTD)
ω
T_{c+}
VARIABLE TORQUE
T_{ca}
0
ROTATIONAL ANGLE
T_{c-}
NEGATIVE (ADV)

FIG. 8

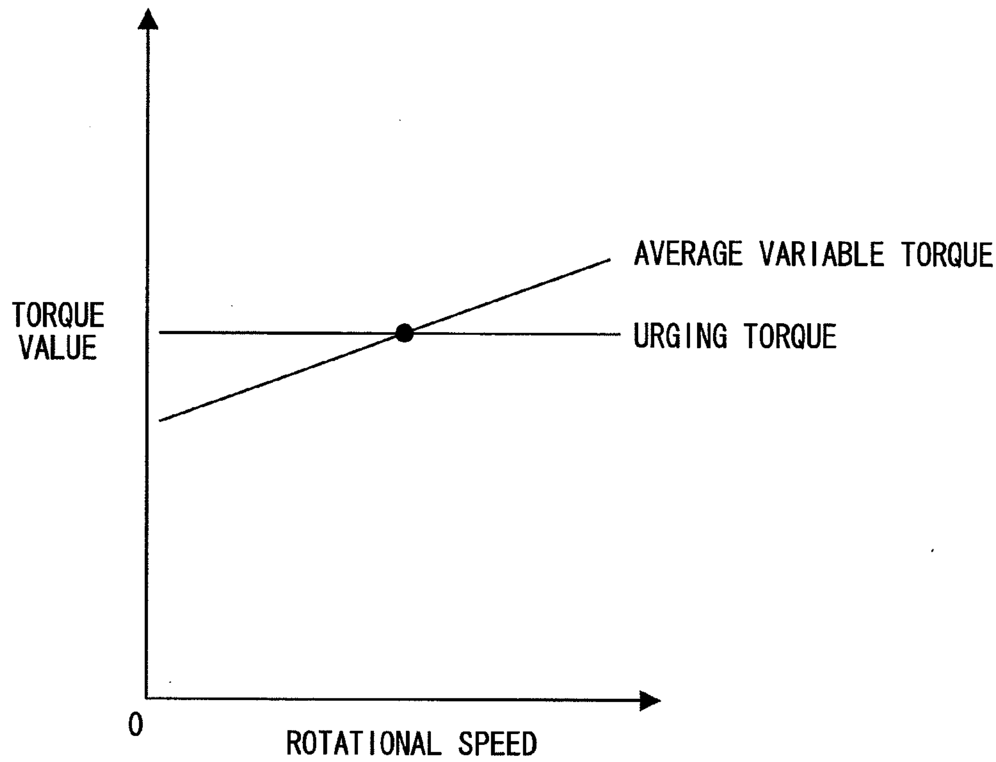


FIG. 9A

FIG. 9B

FIG. 9C

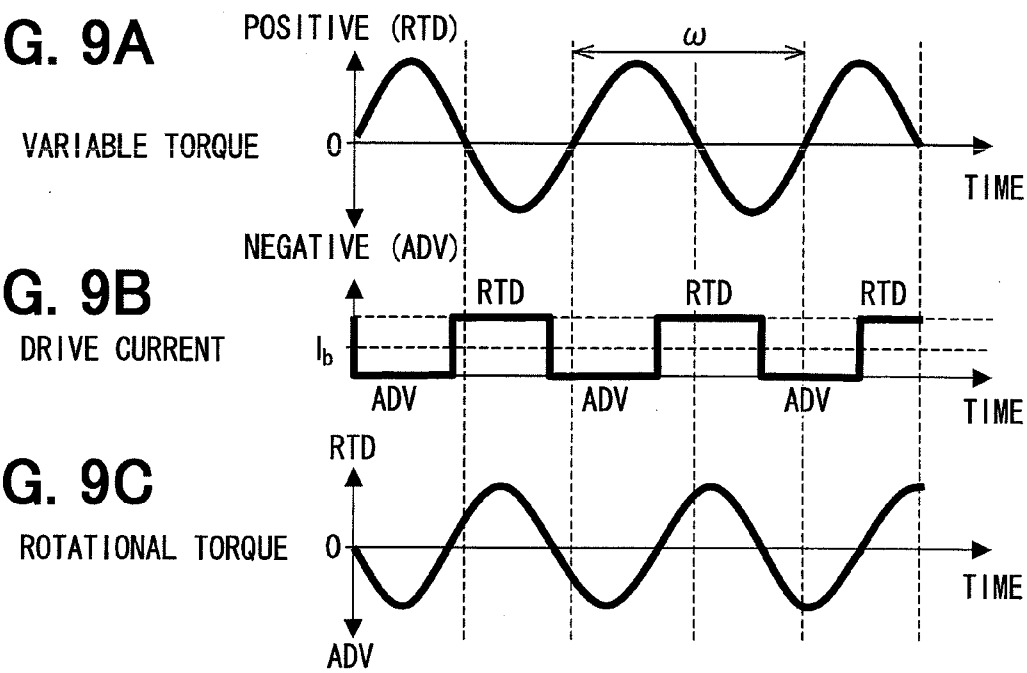


FIG. 10A

FIG. 10B

FIG. 10C

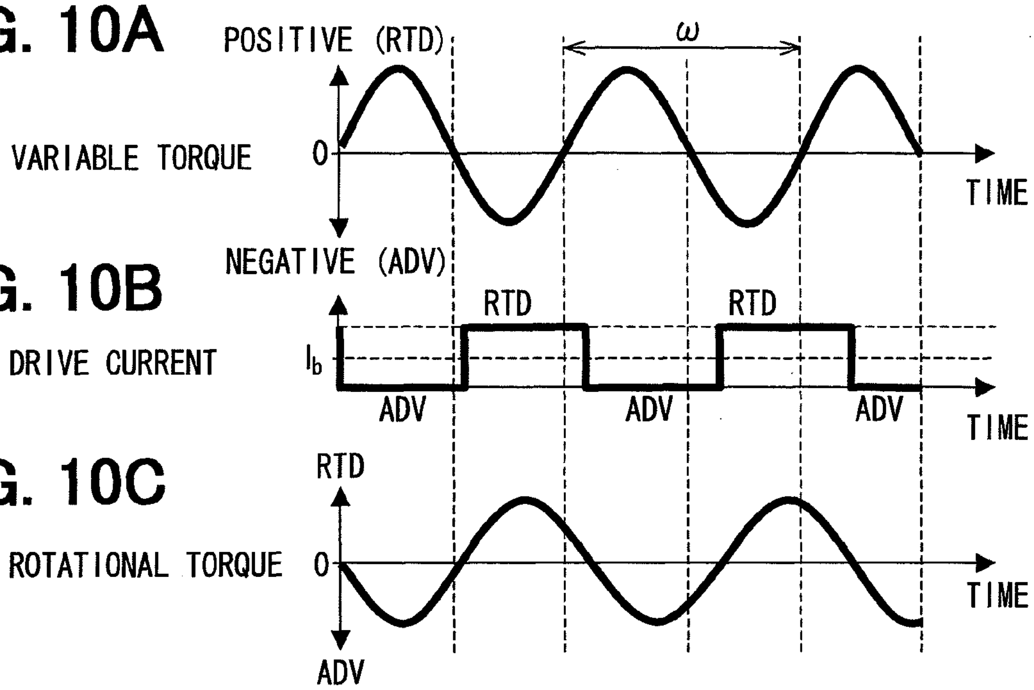


FIG. 11A

FIG. 11B

FIG. 11C

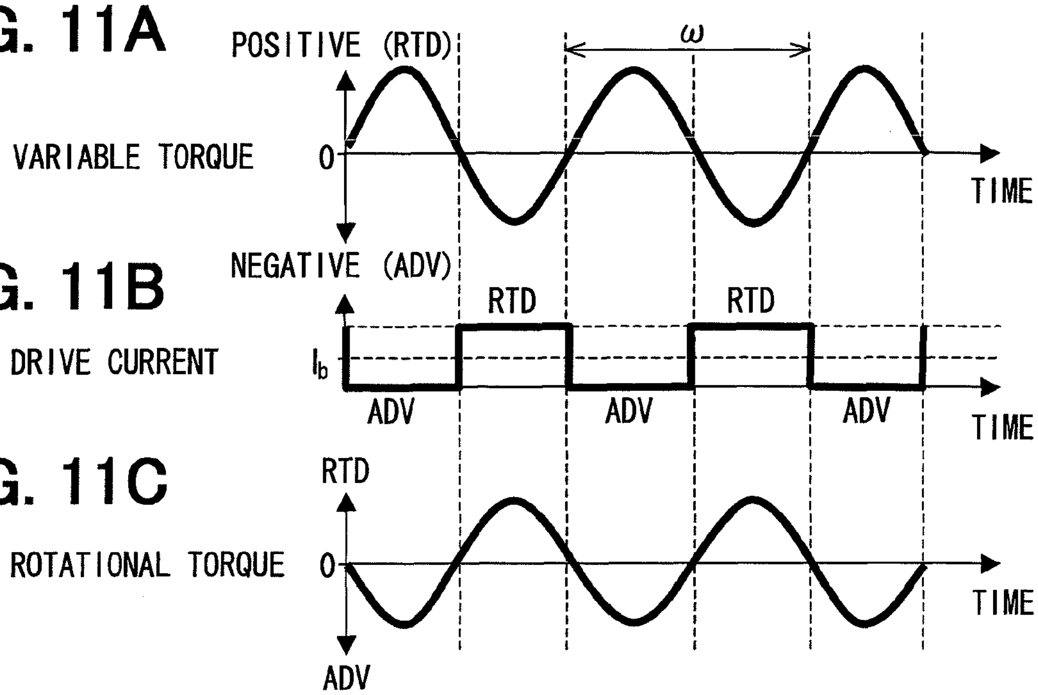


FIG. 12

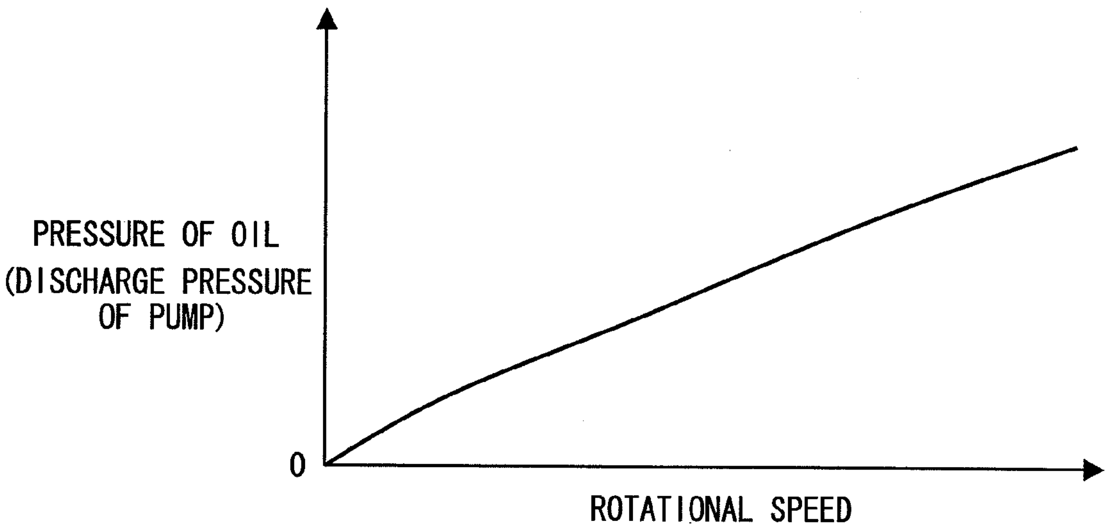

PRESSURE OF OIL
(DISCHARGE PRESSURE
OF PUMP)
0
ROTATIONAL SPEED

FIG. 13

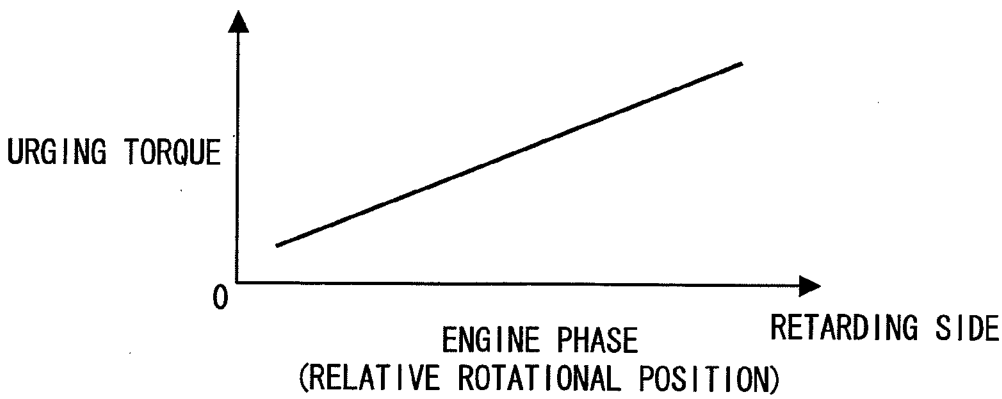
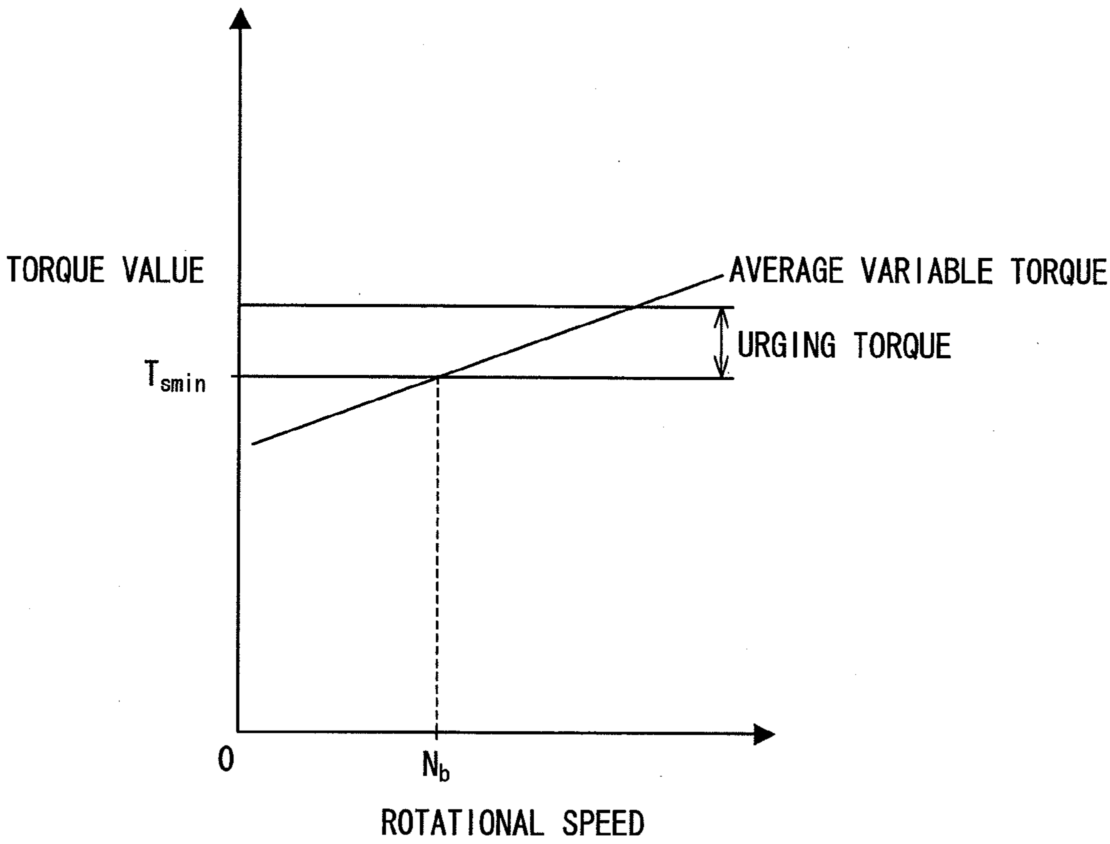

URGING TORQUE
0
ENGINE PHASE
(RELATIVE ROTATIONAL POSITION)
RETARDING SIDE

FIG. 14


TORQUE VALUE
AVERAGE VARIABLE TORQUE
URGING TORQUE
T_{smin}
0
N_b
ROTATIONAL SPEED

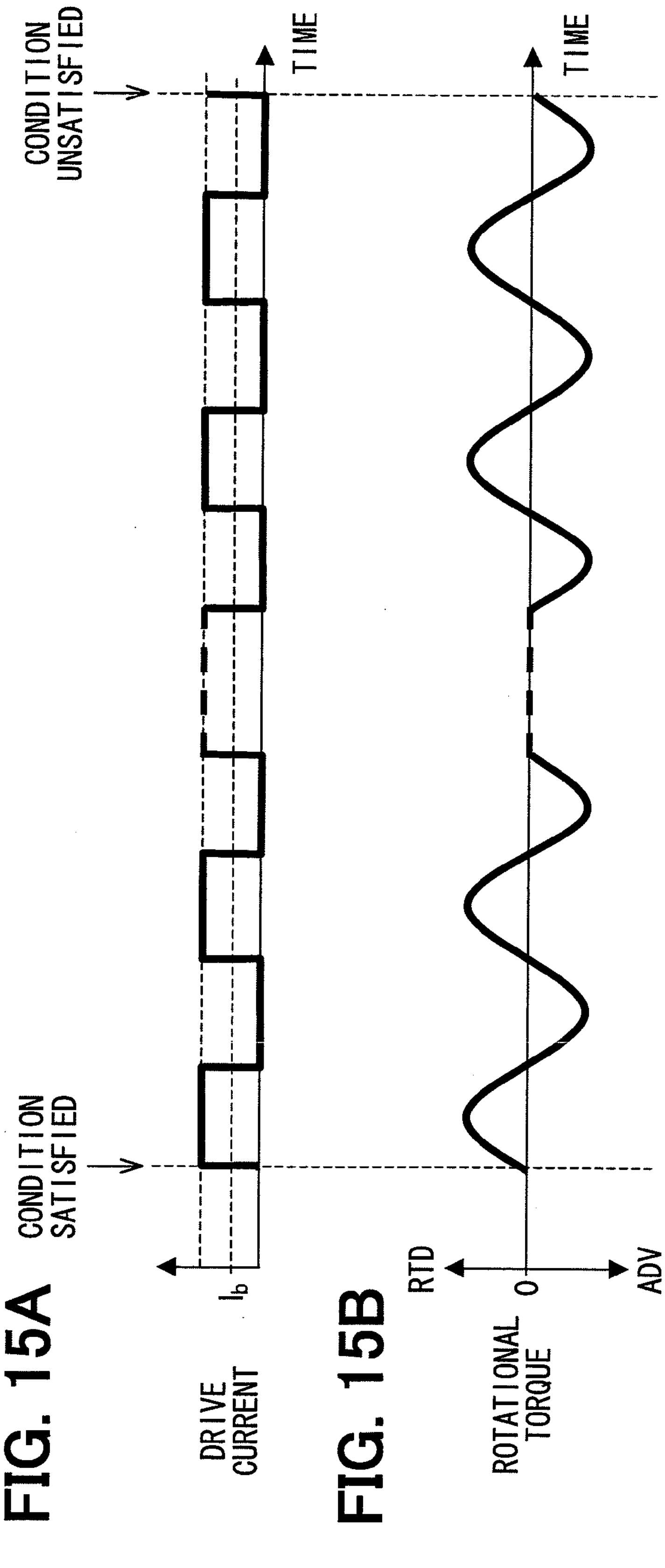


FIG. 15A

FIG. 15B

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EUROPEAN SEARCH REPORT

Application Number
EP 08 16 0496

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2005/028773 A1 (KOMAKI YUSAKU [JP]) 10 February 2005 (2005-02-10) * the whole document * -----	1-8	INV. F01L1/344
X	US 6 332 438 B1 (MACHIDA KENICHI [JP]) 25 December 2001 (2001-12-25) * the whole document * -----	1-8	
X	DE 103 51 223 A1 (HYDRAULIK RING GMBH [DE]) 9 June 2005 (2005-06-09) * the whole document * -----	1-8	
X	US 2002/100445 A1 (TAKENAKA AKIHIKO [JP] ET AL) 1 August 2002 (2002-08-01) * the whole document * -----	1-8	
X	DE 198 44 473 A1 (AISIN SEIKI [JP]) 8 April 1999 (1999-04-08) * the whole document * -----	1-8	
X	DE 103 39 669 A1 (AISIN SEIKI [JP]) 22 April 2004 (2004-04-22) * the whole document * -----	1-8	TECHNICAL FIELDS SEARCHED (IPC) F01L
X	EP 1 365 112 A (DELPHI TECH INC [US]) 26 November 2003 (2003-11-26) * the whole document * -----	1-8	
X	US 2002/152977 A1 (EGUCHI KATSUHIKO [JP] ET AL) 24 October 2002 (2002-10-24) * the whole document * -----	1-8	
X	EP 1 703 087 A (AISIN SEIKI [JP]) 20 September 2006 (2006-09-20) * the whole document * ----- -/--	1-8	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 November 2008	Paulson, Bo

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& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number
EP 08 16 0496

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 533 483 A (TOYOTA MOTOR CO LTD [JP]) 25 May 2005 (2005-05-25) * the whole document * -----	1-8	
X	US 2005/252468 A1 (TANAKA TAKEHIRO [JP] ET AL) 17 November 2005 (2005-11-17) * the whole document * -----	1-8	
X	EP 1 589 197 A (BAYERISCHE MOTOREN WERKE AG [DE]) 26 October 2005 (2005-10-26) * the whole document * -----	1-8	
X	US 7 063 058 B1 (ARMOUR PAUL A [US] ET AL) 20 June 2006 (2006-06-20) * the whole document * -----	1-8	
X	US 2006/060161 A1 (WATANABE KOTARO [JP] ET AL WATANABE KOTARO [JP] ET AL) 23 March 2006 (2006-03-23) * the whole document * -----	1-8	TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 November 2008	Paulson, Bo

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21-11-2008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005028773 A1	10-02-2005	CN 1580504 A DE 102004038645 A1 JP 2005061261 A	16-02-2005 10-03-2005 10-03-2005
US 6332438 B1	25-12-2001	JP 3850598 B2 JP 2001107757 A	29-11-2006 17-04-2001
DE 10351223 A1	09-06-2005	CN 1699728 A US 2005115526 A1	23-11-2005 02-06-2005
US 2002100445 A1	01-08-2002	DE 10203634 A1 GB 2372797 A	19-09-2002 04-09-2002
DE 19844473 A1	08-04-1999	JP 3801747 B2 JP 11101107 A US 6039015 A	26-07-2006 13-04-1999 21-03-2000
DE 10339669 A1	22-04-2004	US 2004221825 A1	11-11-2004
EP 1365112 A	26-11-2003	NONE	
US 2002152977 A1	24-10-2002	DE 10212606 A1 JP 2002276312 A	24-10-2002 25-09-2002
EP 1703087 A	20-09-2006	CN 1886577 A JP 3952015 B2 JP 2005180378 A WO 2005061859 A1	27-12-2006 01-08-2007 07-07-2005 07-07-2005
EP 1533483 A	25-05-2005	CN 1619124 A DE 602004000601 T2 JP 2005147083 A KR 20050048508 A US 2005103296 A1	25-05-2005 25-01-2007 09-06-2005 24-05-2005 19-05-2005
US 2005252468 A1	17-11-2005	JP 2005325758 A	24-11-2005
EP 1589197 A	26-10-2005	DE 102004019773 A1	10-11-2005
US 7063058 B1	20-06-2006	NONE	
US 2006060161 A1	23-03-2006	DE 102005044572 A1 JP 2006083786 A	30-03-2006 30-03-2006

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Patent documents cited in the description

- JP 2006063835 A **[0003] [0004]**