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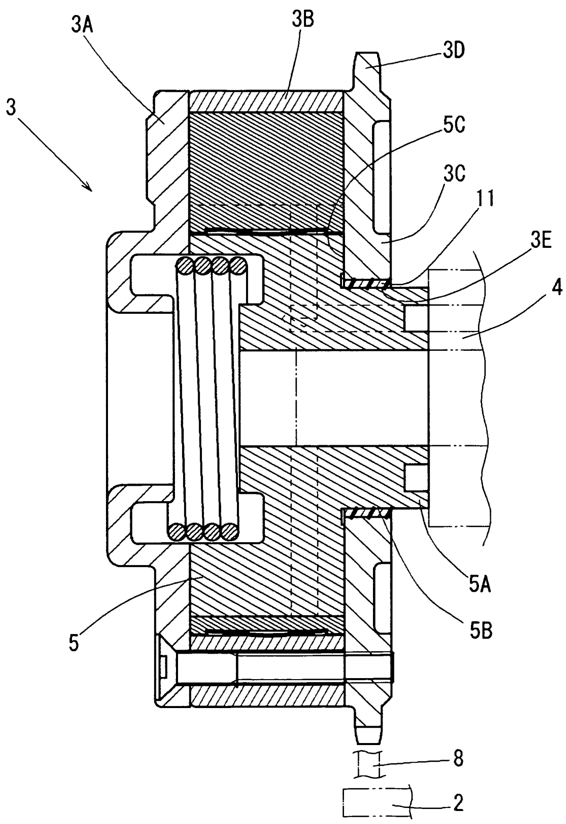
(54) Valve timing control apparatus

(57) A valve timing control apparatus (1) includes a driving-side rotating member (3) having a housing member (3B) and a plate member (3A, 3C), a driven-side rotating member (5) arranged in a coaxial manner relative to the driving-side rotational member (3), a retarded angle chamber (6) and an advanced angle chamber (7) defined by the driving-side rotating member (3) and the driven-side rotating member (5) and used for changing a relative rotational phase of the driven-side rotating member (5) relative to the driving-side rotating member (3) in a retarded angle direction (S2) and in an advanced angle direction (S1) in response to an operation oil supplied to the retarded angle chamber (6) and the retarded angle chamber (7), respectively, and a through hole (3E) formed at one of the housing member (3B) and the plate member (3A, 3C), wherein a first slidably contact portion (5B), which serves as a bearing portion between the driving-side rotating member (3) and the driven-side rotating member (5), has a lower sliding resistance than other slidably contact portions.

F I G. 2



EP 2 305 970 A1

Description

TECHNICAL FIELD

[0001] This disclosure generally relates to a valve timing control apparatus for controlling opening and closing timing of an air intake valve and an exhaust valve of an internal combustion engine.

BACKGROUND

[0002] Generally, a valve timing control apparatus is used for an internal combustion engine such as an engine for a vehicle and the like. Furthermore, the valve timing control apparatus adjusts opening and closing timing of a valve in a manner where the valve timing control apparatus changes a relative rotational phase formed between a driving-side rotating member, which synchronously rotates with a crankshaft, and a driven-side rotating member, which synchronously rotates with a camshaft, in order to achieve an appropriate driving state of the internal combustion engine.

[0003] An improvement in shift speed of the relative rotational phase of the driven-side rotating member relative to the driving-side rotating member is required for the valve timing control apparatus in order to improve fuel efficiency of the internal combustion engine, to reduce gas emission and the like. Furthermore, reduction in an operation hydraulic pressure necessary for shifting the relative rotational phase of the driven-side rotating member relative to the driving-side rotating member is required in order to reduce work load of an oil pump, which supplies oil to the valve timing control apparatus, each sliding member provided at an inside of the internal combustion engine and the like.

[0004] A valve timing control apparatus disclosed in JP4351065B (corresponding U.S. patent No. US6941912) (i.e. an apparatus for adjusting a relative rotational angle of an internal combustion engine relative to a driving wheel) includes a driving-side rotating member (which corresponds to a cell wheel in JP4351065B) rotating together with a crankshaft of the internal combustion engine as a unit, a driven-side rotating member (which corresponds to a rotor in JP4351065B), which is arranged in a coaxial manner relative to the driving-side rotating member and rotates together with a camshaft for opening and closing a valve of the internal combustion engine as a unit, a retarded angle chamber (which corresponds to a pressure space in JP4351065B) used for shifting a relative rotational phase of the driven-side rotating member relative to the driving-side rotating member in a retarded angle direction, and an advanced angle chamber (which corresponds to the pressure space in JP4351065B) used for shifting the relative rotational phase in an advanced angle direction.

[0005] Furthermore, the valve timing control apparatus disclosed in JP4351065B includes plural controlling valves and is configured so as to return the operation oil discharged from one of the retarded angle chamber and the advanced angle chamber to the other one of the retarded angle chamber and the advanced angle chamber by controlling plural controlling valves in order to improve a shift speed of the relative rotational phase, thereby reducing a necessary supply of an operation oil to be supplied from the oil pump to the valve timing control apparatus.

[0006] Generally, the relative rotational phase repeatedly shifts (jiggles) in the advanced angle direction and the retarded angle direction little by little because of a torque fluctuation of the cam. Accordingly, the operation hydraulic pressure within the advanced angle chamber and the retarded angle chamber changes little by little because of the repeated and slight shifts (jiggles) of the relative rotational phase in the advanced angle direction and the retarded angle direction, thereby generating hydraulic pressure pulsation. According to the valve timing control apparatus disclosed in JP4351065B, the control valves need to be opened and closed at a high speed so as to synchronize with the hydraulic pressure pulsation. Specifically, in a case where a temperature of the operation oil is low, viscosity of the operation oil is high. Therefore, the control valves may not be stably opened and closed at the high speed. Furthermore, the valve timing control apparatus disclosed in JP4351065B needs to include plural control valves, which may result in an increase in a number of components used for the valve timing control apparatus. Therefore, the valve timing control apparatus disclosed in JP451065B may not be appropriately adapted to a vehicle engine, whose size is restricted to a size mountable to the vehicle, and may not fit into a limited mounting space in the vehicle. Furthermore, because the number of components used for the valve timing control apparatus disclosed in JP451065B is relatively high because of plural control valves, a weight of the valve timing control apparatus increases, which may interfere with improvement in the fuel consumption of the internal combustion engine.

[0007] A need thus exists to provide a valve timing control apparatus which is not susceptible to the drawback mentioned above, while achieving a shift of a relative rotational phase at an appropriate speed and reducing an operation hydraulic pressure necessary for shifting the relative rotational phase, and further, while achieving a downsize of the valve timing control apparatus.

SUMMARY

[0008] According to an aspect of this disclosure, a valve timing control apparatus includes a driving-side rotating member being synchronously rotatable with a crankshaft of an internal combustion engine, the driving-side rotating member including a housing member formed in a cylindrical shape so that the housing member has an opening portion at one of end portions thereof in an axial direction of the camshaft and a plate member configured so as to close the opening of the housing member, a driven-side rotating member arranged in a coaxial manner relative to the driving-side rotational member and being synchronously rotatable with a camshaft that controls opening and closing operations of a valve of the internal combustion engine, a retarded angle chamber defined by the driving-side rotating member and the driven-side rotating member and used for changing a relative rotational phase of the driven-side rotating member relative to the driving-side rotating member in a retarded angle direction in response to an operation oil supplied to the retarded angle chamber, an advanced angle chamber defined by the driving-side rotating member and the driven-side rotating member and used for changing the relative rotational phase of the driven-side rotating member relative to the driving-side rotating member in an advanced angle direction in response to the operation oil supplied to the advanced angle chamber, and a through hole formed at one of the housing member and the plate member so as to extend in the axial direction of the camshaft so that the driven-side rotating member is connected to the camshaft via the through hole, wherein a bearing portion between the driving-side rotating member and the driven-side rotating member is configured by an inner circumferential surface of the through hole and one of an outer circumferential surface of the driven-side rotating member and an outer circumferential surface of the camshaft, and a first slidably contact portion, which serves as the bearing portion, out of a plurality of slidably contact portions between the driving-side rotating member and the driven-side rotating member is configured so as to have a lower sliding resistance than other slidably contact portions.

[0009] Accordingly, the first slidably contact portion having the bearing portion is configured so as to have the lower sliding resistance when comparing to other slidably contact portions, which are also included in a known valve timing control apparatus. Therefore, other slidably contact portions (i.e. the slidably contact portions except for the first slidably contact portion) do not need to be specifically changed or modified from the known valve timing control apparatus, and materials used for the known driving-side rotating member and the known driven-side rotating member may be used for the driving-side rotating member and the driven-side rotating member of the valve timing control apparatus. Hence, only the sliding resistance of the first slidably contact portion needs to be considered in order to obtain appropriate response speed of the valve timing control apparatus. Accordingly, an increase of material costs and processing cost may be minimized. Furthermore, a shifting speed of the relative rotational phase of the driven-side rotating member relative to the driving-side rotating member may be improved, and an operation hydraulic pressure necessary for shifting the relative rotational phase may be decreased. Furthermore, according to this disclosure, only the first slidably contact portion needs to be considered in order to obtain appropriate response speed of the valve timing control apparatus. Therefore, the valve timing control apparatus of this disclosure may be configured so as to have approximately the same weight as the known valve timing control apparatus.

[0010] According to another aspect of this disclosure, the driven-side rotating member includes a protrusion, which is formed so as to penetrate the through hole to protrude towards the camshaft, and a slidably contact portion between the inner circumferential surface of the through hole and an outer circumferential surface of the protrusion serves as the first slidably contact portion.

[0011] According to a further aspect of this disclosure, the first slidably contact portion is formed of a resin member.

[0012] Accordingly, only the first slidably contact portion, which needs to have the low sliding resistance, is made of the resin member. Therefore, an increase of the manufacturing costs of the valve timing control apparatus may be avoided. Furthermore, the sliding resistance of the first slidably contact portion may be reduced by applying a simple processing to the valve timing control apparatus.

[0013] According to a further aspect of this disclosure, the first slidably contact portion includes a bearing member provided between an inner circumferential surface of the driving-side rotating member on the one hand and one of the outer circumferential surface of driven-side rotating member and the outer circumferential surface of the camshaft on the other hand.

[0014] Accordingly, the bearing member is provided at the first slidably contact portion, which needs to have the low sliding resistance. Therefore, the increase of the manufacturing costs of the valve timing control apparatus may be avoided. Furthermore, the sliding resistance of the first slidably contact portion may be reduced only by adding a simple component thereto.

[0015] According to a further aspect of this disclosure, the valve timing control apparatus further includes a power transmission member transmitting a rotational force generated by the crankshaft. The first slidably contact portion between the driving-side rotating member and the driven-side rotating member receives a tightening force generated by the power transmission member in a radial direction of the driving-side rotating member and is configured so as to have a lower sliding resistance when comparing to other slidably contact portions between the driving-side rotating member and the driven-side rotating member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:

[0017] Fig. 1 is a cross-sectional diagram illustrating a valve timing control apparatus according to a first embodiment;

[0018] Fig. 2 is a diagram illustrating the valve timing control apparatus being viewed in a direction indicated by arrows II-II in Fig. 1;

[0019] Fig. 3 is a diagram schematically illustrating a mounting position of the valve timing control apparatus;

[0020] Fig. 4 is a graph showing a comparison between a response speed of a known valve timing control apparatus and a response speed of the valve timing control apparatus according to the first embodiment; and

[0021] Fig. 5 is a diagram illustrating a valve timing control apparatus according to a second embodiment being viewed in a direction indicated by arrows V-V in Fig. 1.

DETAILED DESCRIPTION

[0022] Embodiments, in which a valve timing control apparatus is adapted to a vehicle engine as a valve timing control apparatus at an air intake valve of the vehicle engine or as a valve timing control apparatus at an exhaust valve of the vehicle engine, will be described below in accordance with the attached drawings.

[0023] [First embodiment]

[0024] A valve timing control apparatus 1 according to a first embodiment includes a driving-side rotating member 3, a driven-side rotating member 5, a retarded angle chamber 6 (in this embodiment, plural retarded angle chambers 6 are formed) and an advanced angle chamber 7 (in this embodiment, plural advanced angle chambers 7 are formed). The driven-side rotating member 3 is configured so as to rotate synchronously with a crankshaft 2 of an engine 100 (an example of an internal combustion engine). The driven-side rotating member 5 is configured so as to be arranged in a coaxial manner relative to the driving-side rotating member 3 and so as to rotate synchronously with a camshaft 4 for opening and closing a vale of the engine 100. Each of the retarded angle chambers 6 is defined by the driving-side rotating member 3 and the driven-side rotating member 5. Similarly, each of the advanced angle chambers 7 is defined by the driving-side rotating member 3 and the driven-side rotating member 5. More specifically, the retarded angle chambers 6 are used for shifting a relative rotational phase of the driven-side rotating member 5 relative to the driving-side rotating member 3 in a retarded angle direction by supplying an oil (an operation oil) thereto. On the other hand, the advanced angle chambers 7 are used for shifting the relative rotational phase in an advanced angle direction by supplying the operation oil thereto. The driven-side rotating member 5 includes a protrusion 5A, which protrudes towards the camshaft 4.

[0025] The driving-side rotating member 3 includes a housing 3B (a housing member), a front plate 3A (a plate member) and a rear plate 3C (the plate member). The housing 3B is arranged at an outer circumferential portion of the driven-side rotating member 3 in a radial direction thereof. The front plate 3A is arranged at a portion of the driving-side rotating member 3 opposite from the camshaft 4 relative to the housing 3B. The rear plate 3C is arranged at a portion of the driving-side rotating member 3 closer to the camshaft 4 relative to the housing 3B.

[0026] A timing sprocket 3D is formed at an outer circumferential surface of the rear plate 3C. A power transmission member 8, such as a timing chain, a timing belt or the like, is provided between the timing sprocket 3D and a gear 101 attached at the crankshaft 2 of the engine 100.

[0027] The rear plate 3C includes a through hole 3E, which extends in an axial direction of the camshaft 4 and through which the protrusion 5A of the driven-side rotating member 5 is connected with the camshaft 4. Accordingly, the protrusion 5A penetrates the rear plate 3C so as to protrude towards the camshaft 4 to a greater extent than the rear plate 3C when the driving-side rotating member 3 and the driven-side rotating member 5 are assembled.

[0028] Plural protruding portions 3F are formed at an inner circumferential portion of the housing 3B so as to inwardly protrude in a radial direction thereof while keeping a distance between the neighboring protruding portions 3F in a rotational direction of the housing 3B. Furthermore, a withdrawal groove 9B and an accommodation bore 9D are formed at the inner circumferential portion of the housing 3B. The withdrawal groove 9B is configured so as to accommodate therewithin a lock member 9A. The accommodation bore 9D is configured so as to be in communication with the withdrawal groove 9B and so as to accommodate therewithin a spring 9C for inwardly biasing the lock member 9A in the radial direction.

[0029] The driven-side rotating member 5 is integrally assembled at an edge portion of the camshaft 4, which configures a rotating shaft of the cam that controls the opening and closing timing of the air intake value or the exhaust vale of the engine 100. Furthermore, the driven-side rotating member 5 is provided within the driving-side rotating member 3 while allowing the driven-side rotating member 5 to be rotatable relative to the driving-side rotating member 3 in a predetermined relative rotational range. A lock groove 9E is formed at the driven-side rotating member 5. More specifically, the lock groove 9E is configured so as to accommodate therewithin the lock member 9A when the lock member 9A is inwardly displaced in the radial direction. Additionally, the driven-side rotating member 5 includes the protrusion 5A, which protrude towards the camshaft 4. In this embodiment, the protrusion 5A is configured so as to protrude towards the camshaft 4 to the greater extent than the rear plate 3C.

[0030] A lock mechanism 9 includes the lock member 9A, the withdrawal groove 9B, the spring 9C, the accommodation bore 9D and the lock groove 9E.

[0031] A space defined by the driving-side rotating member 3 and the driven-side rotating member 5 between the neighboring protruding portions 3F is divided into two chambers (i.e. the retarded angle chamber 6 and the advanced angle chamber 7) by means of a vane 10. In this embodiment, the valve timing control apparatus 1 includes four retarded angle chambers 6 and four advanced angle chambers 7.

[0032] The relative rotatable range of the driven-side rotating member 5 relative to the driving-side rotating member 3 corresponds to a moving range of the vane 10 in an advanced angle direction S1 or in a retarded angle direction S1 until the vane 10 contacts the protruding portion 3F, in other words, a range between a most advanced angle phase and a most retarded angle phase (including the most advanced angle phase and the most retarded angle phase).

[0033] Slidably contact portions between the driving-side rotating member 3 and the driven-side rotating member 5 according to the first embodiment include slidably contact portion between the protruding portions 3F of the driving-side rotating member 3 and an outer circumferential surface of the driven-side rotating member 5, a slidably contact portion between the front plate 3A and a surface of the driven-side rotating member 3 facing the front plate 3A and a slidably contact portion between the rear plate 3C and a surface of the driven-side rotating member 3 facing the rear plate 3C. The slidably contact portion between the rear plate 3C and the surface of the driven-side rotating member 3 facing the rear plate 3C includes a first slidably contact portion 5B and a second slidably contact portion 5C. More specifically, the first slidably contact portion 5B includes an outer circumferential surface of the protrusion 5A of the driven-side rotating member 5 and an inner circumferential surface of the through hole 3E, which is formed in a circular shape at the rear plate 3C. The outer circumferential surface of the protrusion 5A of the driven-side rotating member 5 and an inner circumferential surface of the through hole 3E slidably contact each other. The second slidably contact portion 5C includes a side surface of the rear plate 3C and a side surface of the driven-side rotating member 5, except for the protrusion 4A, which slidably contact each other.

[0034] The slidably contact portion 5B serves as a bearing portion between at least one of the camshaft 4 and the driven-side rotating member 5 on the one hand and the driving-side rotating member 3 on the other hand. A relatively great force is likely to act on the first slidably contact portion 5B in a predetermined radial direction of the camshaft 4, in other words, the force generated in the radial direction of the camshaft 4 is not likely to act equally on entire first slidably contact portion 5B. More specifically, as illustrated in Fig. 3, a rotational force generated by the crankshaft 2 is transmitted to the valve timing control apparatus 1 via the power transmission member 8. In Fig. 3, the power transmission member 8 connects two valve timing control apparatuses 1 and the gear 101 of the crankshaft 2. More specifically, the power transmission member 8 is provided around the valve timing control apparatuses 1 and the gear 101 of the crankshaft 2 so as to tighten up the valve timing control apparatuses 1 and the gear 101 towards a rotational center of the power transmission member 8 in order to avoid unintentional disengagement of the power transmission member 8 from the valve timing control apparatuses 1. Therefore, a tightening force F acts in the radial direction of each of the valve timing control apparatuses 1. Hence, the force F in the predetermined radial direction acts on the first slidably contact portion 5B. Accordingly, a sliding resistance at the valve timing control apparatus 1 becomes great because of the force F acting on the first slidably contact portion 5B.

[0035] Therefore, a resin member 11, which is expected to reduce the sliding resistance, may be used to form the first slidably contact portion 5B. More specifically, a polytetrafluoroethylene resin having oil resistance and heat resistance may be used to form the first slidably contact portion 5B.

[0036] Accordingly, by forming the first slidably contact portion 5B by using the resin member 11, the sliding resistance generated between the inner circumferential surface of the rear plate 3C and the outer circumferential surface of the protrusion 5A may be reduced. As a result, a shifting speed of the relative rotational phase of the driven-side rotating member 5 relative to the driving-side rotating member 3 may be improved. Furthermore, an operation hydraulic pressure necessary for shifting the relative rotational phase formed between the driving-side rotating member 3 and the driven-side rotating member 5 may be reduced.

[0037] The resin member 11, which is expected to reduce the sliding resistance, may be adapted to the valve timing control apparatus to form the first slidably contact portion 5B in a manner where a surface treatment is applied to the outer circumferential surface of the protrusion 5A and the inner circumferential surface of the through hole 3E formed in the circular shape at the rear plate 3C, or a cylindrical shaped bush may be press-fitted onto the outer circumferential surface of the protrusion 5A or into the inner circumferential surface of the through hole 3E formed in the circular shape at the rear plate 3C.

[0038] A graph illustrated in Fig. 4 is a measurement data obtained by comparing a response speed of a known valve timing control apparatus (which is indicated as "Type 1" in the graph) and a response speed of the valve timing control apparatus 1 according to the embodiment (which is indicated as "Type 2" in the graph). The response speeds in a case where a valve lift amount of the air intake valve is small (which is indicated as "Low Lift" in the graph) and where the valve lift amount is great (which is indicated as "High Lift" in the graph) are measured. Furthermore, the response speeds are measured under a condition where an engine rotational number (i.e. an engine rotational speed) is 600 rotations per minute (which is indicated as 600rpm in the graph), under a condition where the engine rotational number is 800 rotations per minute (which is indicated as 800rpm in the graph), and under a condition where the engine rotational number is 1000 rotations per minute (which is indicated as 1000prm in the graph). A vertical axis indicates an average value of the response speed in a case where the relative rotational phase of the driven-side rotating member 5 relative to the driving-side rotating member 3 is shifted in the advanced angle direction S1 and an average value of the response speed in a case where the relative rotational phase is shifted in the retarded angle direction S2 (refer to "Response speed" in the graph). Additionally, the response speeds are measured in the same condition (for example, the same type of an operation oil is used, an oil temperature is maintained at the same, the valve timing control apparatuses are shaped in the same, volumes of the advanced angle chambers are set to be the same, volumes of the retarded angle chambers are set to be the same, and the like) for the known valve timing control apparatus and the valve timing control apparatus 1 according to the embodiment.

[0039] As is evident from the graph illustrated in Fig. 4, the response speed of the valve timing control apparatus 1 according to the embodiment is improved at any engine rotational number (i.e. the engine rotational speed) when comparing to the know valve timing control apparatus. Specifically, the lower the engine rotational number is, the more the response speed of the valve timing control apparatus 1 is improved. The measurement results show that a difference in the sliding resistances between the first slidably contact portion 5B of the valve timing control apparatus according to the first embodiment and the corresponding slidably contact portion of the known valve timing control apparatus is prominently reflected to the difference in response speeds between the valve timing control apparatus 1 according to the first embodiment and the known valve timing control apparatus. More specifically, in the case where the engine rotational number becomes lower, a rotational number (i.e. a rotational speed) of an oil pump, which is actuated in response to the rotational force of the crankshaft 2, becomes also lower, therefore, the hydraulic pressure acting on the advanced chambers 6 and the retarded chambers 7 becomes low. Hence, in the case where the hydraulic pressure acting on the advanced chambers 6 and the retarded chambers 7 is low, the relative rotational phase established between the driving-side rotating member 3 and the driven-side rotating member 5 of the valve timing control apparatus 1 according to the embodiment is quickly shifted when comparing to the known valve timing control apparatus, because the sliding resistance of the first slidably contact portion 5B is low and therefore, the necessary hydraulic pressure to shift the relative rotational phase is low. Furthermore, when comparing to the response speeds in the case where the valve lift amount is great and the response speeds in the case where the valve lift amount is small, the response speed of the valve timing control apparatus 1 according to the embodiment is further improved as the valve lift amount becomes lower when comparing to the known valve timing control apparatus. The measurement results show that the difference in the sliding resistances between the first slidably contact portion 5B of the valve timing control apparatus 1 according to the first embodiment and the corresponding sliding surface of the known valve timing control apparatus is prominently reflected to the difference in the response speeds between the valve timing control apparatus 1 according to the first embodiment and the known valve timing control apparatus according. More specifically, the response speed of the valve timing control apparatus 1 according to the embodiment is considered to be improved in a case where a torque fluctuation becomes lower as the valve lift amount becomes lower because of the relatively low sliding resistance of the first slidably contact portion 5B. Accordingly, as is verified by the measurement results indicated in Fig. 4, the valve timing control apparatus 1 according to the first embodiment achieves improvement in response speed.

[0040] [Second embodiment]

[0041] A second embodiment of the valve timing control apparatus 1 will be described below. The valve timing control apparatus 1 according to the second embodiment differs from the valve timing control apparatus 1 according to the first embodiment in that the valve timing control apparatus 1 according to the second embodiment includes a ball bearing 12 (a bearing member) having the first slidably contact portion 5B in stead of the resin member 11 having the first slidably contact portion 5B. In the case where the ball bearing 12 is provided at the valve timing control apparatus 1, an oil providing groove 13 may be formed at the surface of the driven-side rotating member 5 facing the rear plate 3C, so that an oil is provided between the outer circumferential surface of the protrusion 5A and an inner circumferential surface of the ball bearing 12. According to the second embodiment, as is the case with the first embodiment, the shifting speed of the relative rotational phase of the driven-side rotating member 5 relative to the driving-side rotating member 3 may be improved. Furthermore, the operation hydraulic pressure necessary for shifting the relative rotational phase may be reduced.

[0042] [Other embodiments]

[0043] In the first and second embodiments, the driven-side rotating member 5 includes the protrusion 5A protruding to the camshaft 4. However, the driven-side rotating member 5 may be modified so as not to include the protrusion 5A. Instead, in this case, the camshaft 4 may be modified so as to extend until the camshaft 4 penetrates the through hole 3E of the rear plate 3C in order to connect the camshaft 4 with the rear plate 3C. In this case, the first slidably contact portion 5B, which serves as the bearing portion, configures the bearing portion (the bearing member) together with the through hole 3E of the rear plate 3C and the outer circumferential surface of the camshaft 4 facing the rear plate 3C.

[0044] In the first and second embodiments, the driving-side rotating member 3 includes the housing 3B, the front plate 3A and the rear plate 3C. However, the driving-side rotating member 3 does not necessarily need to include the housing 3B, the front plate 4A and the rear plate 3C individually and separately from each other. For example, the driving-side rotating member 3 may be modified so that the front plate 3A and the housing 3B are integrally formed, or the housing 3B and the rear plate 3C are integrally formed.

Claims

1. A valve timing control apparatus (1) comprising:

   a driving-side rotating member (3) being synchronously rotatable with a crankshaft (2) of an internal combustion engine (100), the driving-side rotating member (3) including a housing member (3B) formed in a cylindrical shape so that the housing member (3B) has an opening portion at one of end portions thereof in an axial direction of the camshaft (4) and a plate member (3A, 3C) configured so as to close the opening of the housing member (3B);
   a driven-side rotating member (5) arranged in a coaxial manner relative to the driving-side rotational member (3) and being synchronously rotatable with a camshaft (4) that controls opening and closing operations of a valve of the internal combustion engine (100);
   a retarded angle chamber (6) defined by the driving-side rotating member (3) and the driven-side rotating member (5) and used for changing a relative rotational phase of the driven-side rotating member (5) relative to the driving-side rotating member (3) in a retarded angle direction (S2) in response to an operation oil supplied to the retarded angle chamber (6);
   an advanced angle chamber (7) defined by the driving-side rotating member (3) and the driven-side rotating member (5) and used for changing the relative rotational phase of the driven-side rotating member (5) relative to the driving-side rotating member (3) in an advanced angle direction (S1) in response to the operation oil supplied to the advanced angle chamber (7); and
   a through hole (3E) formed at one of the housing member (3B) and the plate member (3A, 3C) so as to extend in the axial direction of the camshaft (4) so that the driven-side rotating member (5) is connected to the camshaft (4) via the through hole (3E), wherein
   a bearing portion between the driving-side rotating member (3) and the driven-side rotating member (5) is configured by an inner circumferential surface of the through hole (3E) and one of an outer circumferential surface of the driven-side rotating member (5) and an outer circumferential surface of the camshaft (4), and
   a first slidably contact portion (5B), which serves as the bearing portion, out of a plurality of slidably contact portions between the driving-side rotating member (3) and the driven-side rotating member (5) is configured so as to have a lower sliding resistance than other slidably contact portions.

2. The valve timing control apparatus (1) according to Claim 1, wherein the driven-side rotating member (5) includes a protrusion (5A), which is formed so as to penetrate the through hole (3E) to protrude towards the camshaft (4), and a slidably contact portion between the inner circumferential surface of the through hole (3E) and an outer circumferential surface of the protrusion (5A) serves as the first slidably contact portion (5B).

3. The valve timing control apparatus (1) according to Claim 1 or Claim 2, wherein the first slidably contact portion (5B) is formed of a resin member (11).

4. The valve timing control apparatus (1) according to Claim 1 or Claim 2, wherein the first slidably contact portion (5B) includes a bearing member provided between an inner circumferential surface of the driving-side rotating member (5) on the one hand and one of the outer circumferential surface of driven-side rotating member (3) and the outer circumferential surface of the camshaft (4) on the other hand.

5. The valve timing control apparatus (1) according to any one of Claims 1 to 4 further comprising a power transmission member (8) transmitting a rotational force generated by the crankshaft (2), wherein the first slidably contact portion between the driving-side rotating member (3) and the driven-side rotating member (5) receives a tightening force generated by the power transmission member (8) in a radial direction of the driving-side rotating member (3) and is configured so as to have a lower sliding resistance when comparing to other slidably contact portions between the driving-side rotating member (3) and the driven-side rotating member (5).

FIG. 1

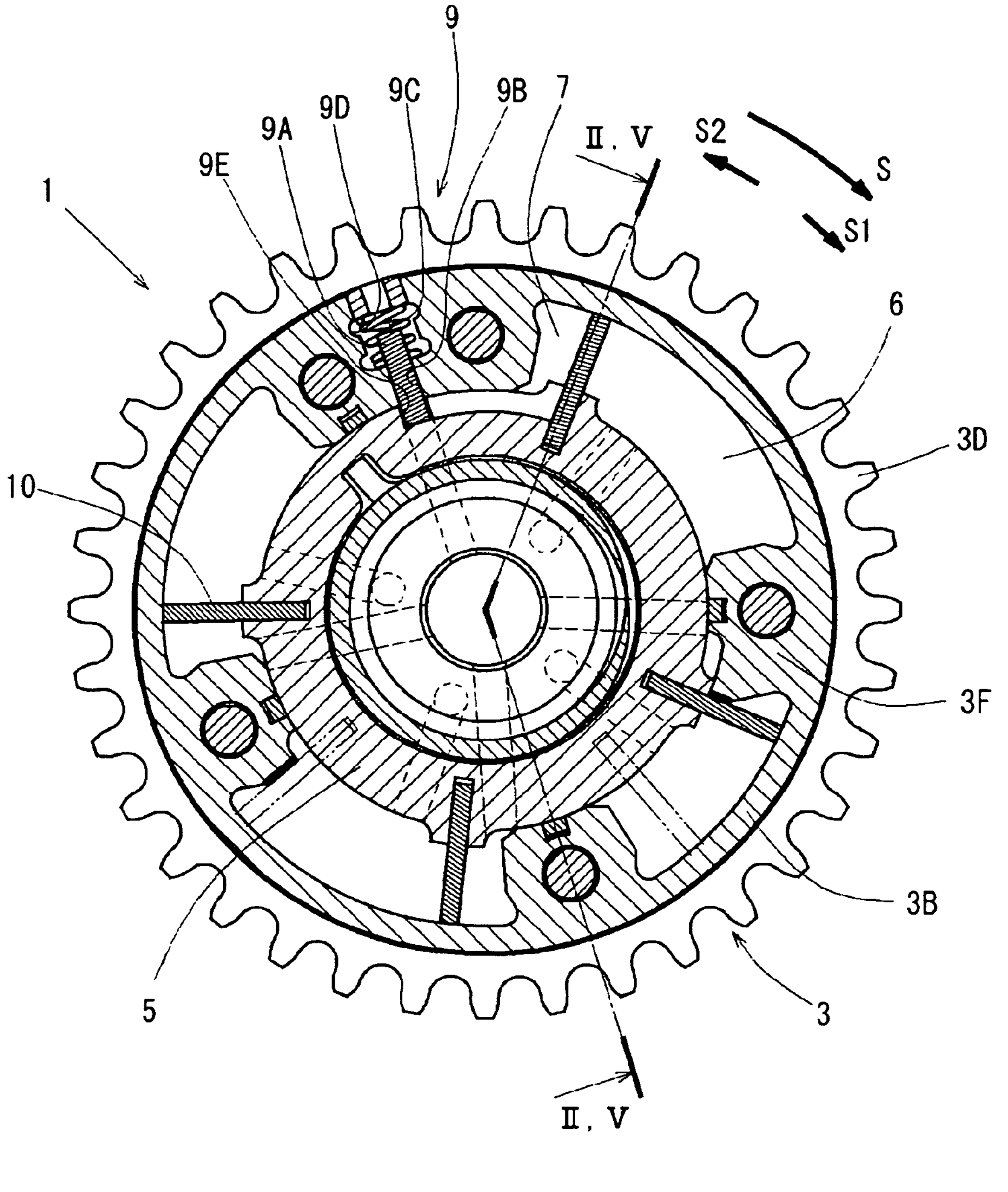


FIG. 2

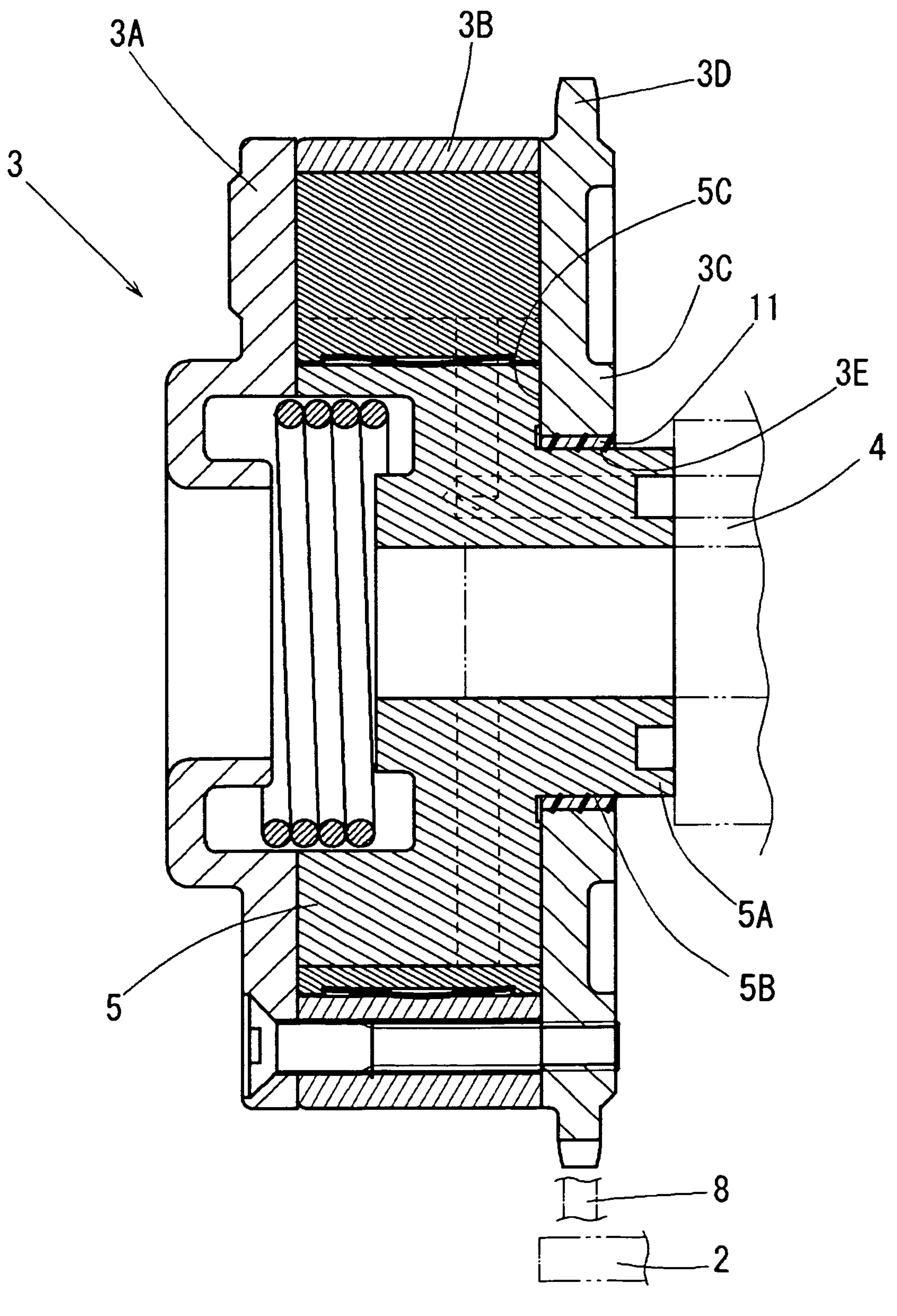


FIG. 3

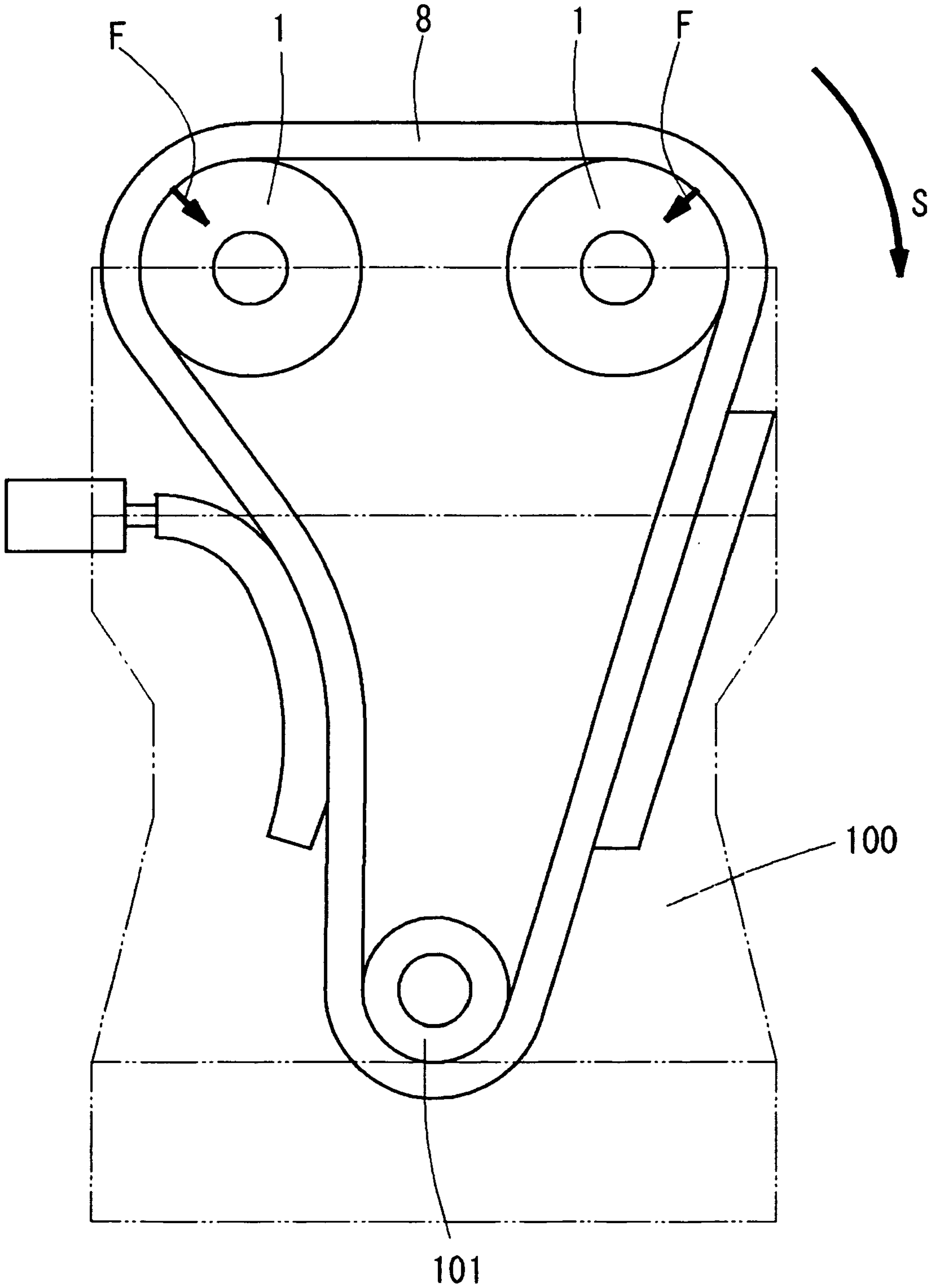


FIG. 4

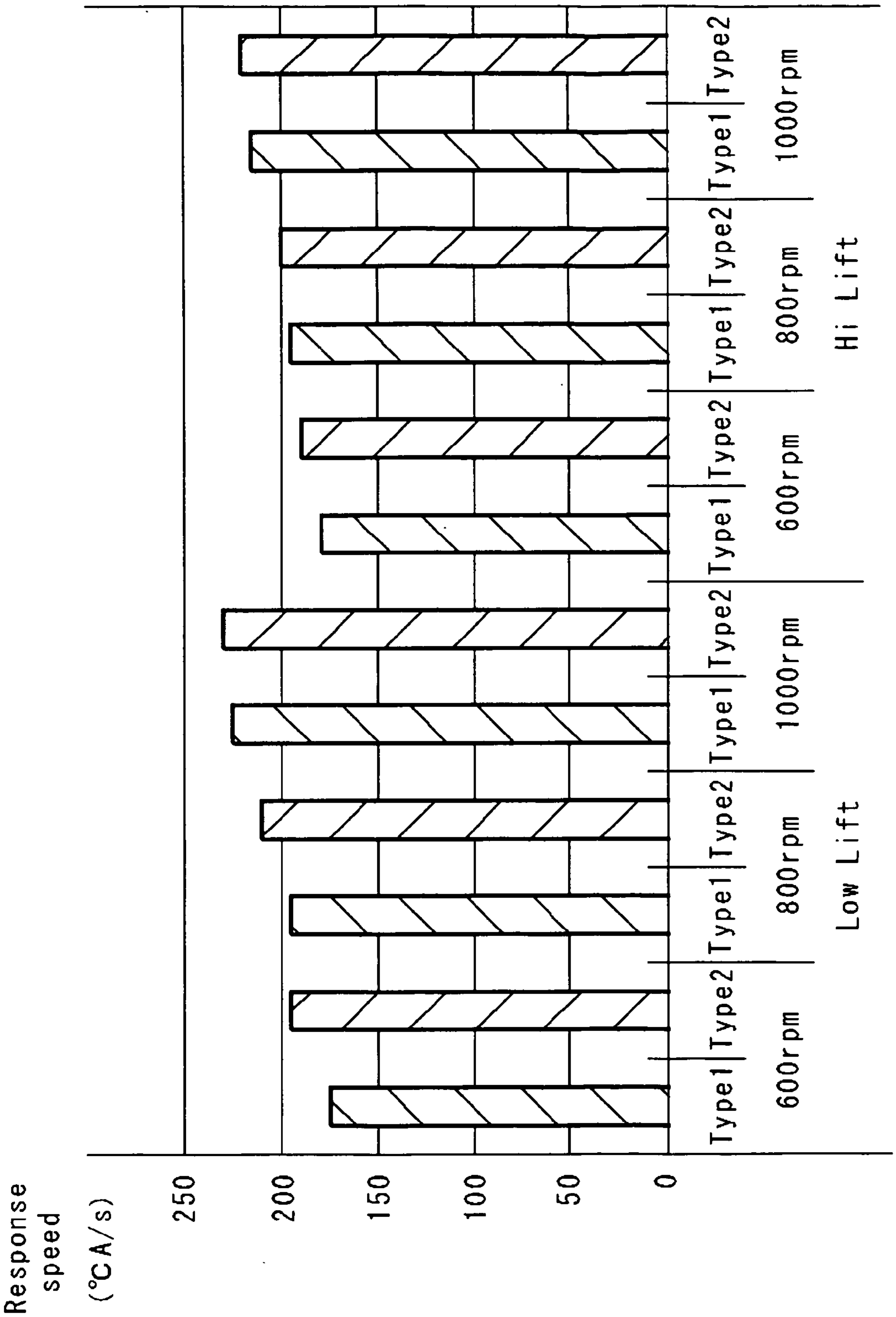
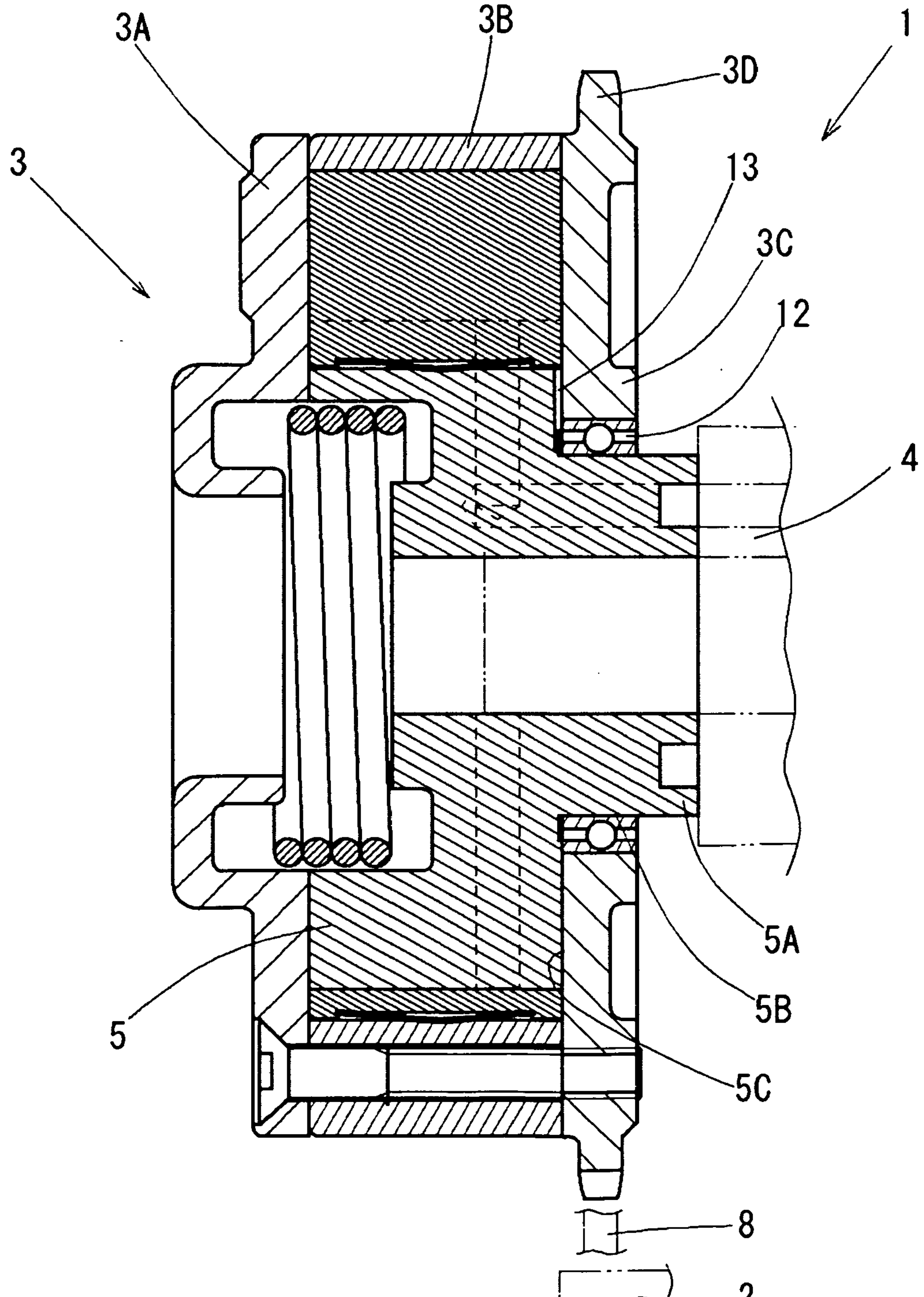

Response speed (°CA/s)
250
200
150
100
50
0
Type1
Type2
600rpm
800rpm
1000rpm
Low Lift
Hi Lift

FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 10 00 6156

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