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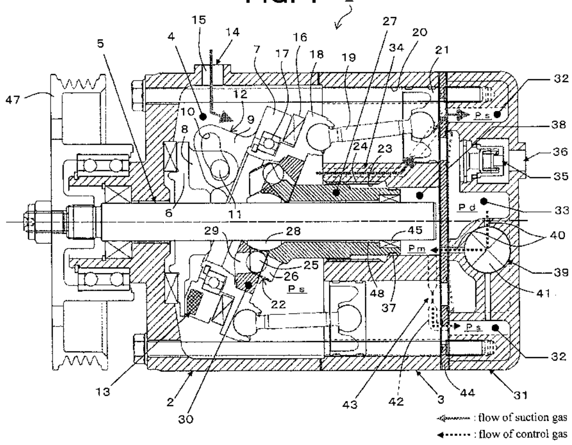
(54) **VARIABLE DISPLACEMENT COMPRESSOR**

(57) Disclosed is a variable displacement compressor having improved compressor performance such as reduced pulsation and improved durability and resistance to pressure and allowing smooth and high-precision control of a swash plate tilt angle at a target tilt angle by using an axial movement member. The variable displacement compressor is provided with a cylinder head in which a suction chamber and a discharge chamber are formed, a cylinder block having a cylinder bore into which a piston is inserted at a condition capable of being reciprocated, a crank chamber formed by the cylinder block and a front housing, a swash plate which is disposed in the crank chamber and which is rotated with a main shaft and is supported so that the tilt angle thereof can be changed relative to the main shaft, and a movement conversion mechanism for converting the rotational movement of the swash plate to the reciprocating movement of the piston, wherein: a suction path for intake of a suction gas into the compressor is formed so as to open into the crank chamber; a communication path for communicating the crank chamber and the suction chamber is provided in the cylinder block; around the main shaft, an axial movement member is provided that can move in a direction along the axis of the main shaft in an essentially one to one correspondence with the tilt angle of the swash plate; the axial movement member is disposed such that one end is applied with the pressure in the crank chamber, and the other end is applied with an intermediate pressure between the pressure in the discharge chamber and the pressure in the suction chamber; and an intermediate pressure control mechanism which can control the intermediate pressure is also provided.

FIG. 1



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Description

Technical Field of the Invention

[0001] The present invention relates to a variable displacement compressor, and specifically, to a variable displacement compressor in which reduction of pulsation and improvement of durability and resistance to pressure can be performed and a tilt angle of a swash plate can be controlled more smoothly and precisely via an axial movement member.

Background Art of the Invention

[0002] A variable displacement compressor is well known which is provided with a cylinder head in which a suction chamber and a discharge chamber are formed, a cylinder block having a cylinder bore into which a piston is inserted at a condition capable of being reciprocated, a crank chamber formed by the cylinder block and a front housing, a swash plate which is disposed in the crank chamber and which is rotated with a main shaft and is supported so that a tilt angle thereof can be changed relative to the main shaft, and a movement conversion mechanism for converting rotational movement of the swash plate to reciprocating movement of the piston.

[0003] Further, as a variable displacement compressor relating to the present invention, previously by the applicant of the present application, a wabble plate type variable displacement compressor is proposed wherein the above-described movement conversion mechanism has a wabble plate in which a rotational movement of the swash plate is converted into a wabble movement of the wabble plate, and which transmits the wabble movement to the pistons to reciprocate the pistons, and a rotation preventing mechanism of the wabble plate, and the rotation preventing mechanism of the wabble plate comprises (a) an inner ring provided in a housing movably in an axial direction while being prevented with rotation and having a plurality of guide grooves for guiding a plurality of balls provided for power transmission, (b) an outer ring having a plurality of guide grooves for guiding the balls at positions opposing respective guide grooves of the inner ring, connected with the wabble plate on an outer circumference of the outer ring and supported at a condition capable of being wabbled together with the wabble plate, and (c) a plurality of balls held by the guide grooves formed in the inner ring and the outer ring at a condition of opposing each other and performing power transmission by being compressed between the guide grooves (Patent document 1). In the variable displacement compressor having such a structure, the above-described inner ring forms an axial movement member capable of moving in a direction along an axis of the main shaft in an essentially one to one correspondence with the tilt angle of the swash plate.

[0004] The above-described variable displacement compressor previously proposed by the applicant of the present application concretely has a structure, for example, as shown in Figs. 11 and 12. Fig. 11 shows a state achieving the maximum displacement (maximum cam angle [maximum swash plate angle]) and Fig. 12 shows a state achieving the minimum displacement (minimum cam angle [minimum swash plate angle]), respectively. In the figures, relatively to a main shaft 204 inserted in a crank chamber 203 formed by a front housing 201 and a cylinder block 202, a swash plate 206 is provided at a condition capable of changing its tilt angle and being rotated integrally with main shaft 204 via a hinge mechanism 205. The rotational movement of swash plate 206 is converted into the wabble movement of a wabble plate 207, and the wabble movement is converted into the reciprocal movement of a piston 209 via a connecting rod 208. In the example shown in the figures, a rotation preventing mechanism 210 of wabble plate 207 comprises (i) an inner ring 213 provided movably in an axial direction although the rotation is prevented through a spline engagement mechanism 211, provided free to be rotated relatively to main shaft 204, and having a plurality of guide grooves for guiding a plurality of balls 212 provided for power transmission, (ii) a sleeve 214 functioning as a wabble central member of the wabble movement of wabble plate 207, provided at a condition capable of rotating and moving in an axial direction relatively to main shaft 204, and engaged with inner ring 213 movably in an axial direction together with inner ring 213, (iii) an outer ring 214 having a plurality of guide grooves for guiding balls 212 at positions opposing respective guide grooves of inner ring 213, supported on sleeve 214 wabblingly, and supporting wabble plate 207 fixedly on its outer circumference, and (iv) a plurality of balls 212 held by the guide grooves formed in inner ring 213 and outer ring 215 at a condition of opposing each other and performing power transmission by being compressed between the guide grooves. A suction chamber 217 and a discharge chamber 218 are formed in a cylinder head 216. The intake gas to the compressor is taken into suction chamber 217 from a suction port 219 through a suction throttle valve 220 in the example shown in the figures, the gas compressed in a cylinder bore 221 by piston 209 is discharged into discharge chamber 218, and in the example shown in the figures, therefrom the gas is sent to an external circuit through a discharge interruption valve 222 and a discharge port 223.

[0005] Then, in conventional variable displacement compressors including the aforementioned conventional general variable displacement compressor and the above-described wabble plate type variable displacement compressor previously proposed by the applicant of the present application, as exemplified also in Fig. 11, usually, a communication path 225 for introducing the discharge gas controlled from the pressure Pd in discharge chamber 218 by a control valve 224 or a throttle into crank chamber 203 and a communication path 227 for returning the crank chamber gas to suction chamber 217 side (pressure: Ps) through a control valve or a throttle 226 are provided, and by changing the opening degree of control valve 224, the gas pressure Pc in crank chamber 203 is controlled.

[0006] In the variable displacement compressor having such a structure, for comparison with the present invention described later, balance of a couple moment in the compressor will be explained. In the compressor, a couple moment generated by the rotation of rotational parts including swash plate 206 system parts (in case having wabble plate 207, a structure including the wabble plate 207), and a couple moment generated by the reciprocal movement of reciprocal movement system parts including piston 209 system parts, are generated as a couple moment acting in a direction for changing a cam angle by the operation of the compressor, in accordance with the cam angle, for example, as shown in Fig. 13, and the total couple moment due to the rotational and reciprocal movements of those parts becomes, for example, as shown in Fig. 13 (in the example shown in the figure, the total couple moment acts in a direction for increasing the displacement (cam angle) at every cam angle). Then, separately from the couple moment due to the rotational and reciprocal movements of these parts, because distributions of gas pressure are generated in respective spaces in the compressor by the compression operation of the compressor and the pressure control operation of control valves, by these distributions of gas pressure, for example, as shown in Fig. 14, a couple moment in a direction for increasing or decreasing the cam angle is generated. In practice, because the compression operation is generated by the rotation of main shaft 204 of the compressor, during the operation of the compressor the couple moment due to the rotational and reciprocal movements of the respective parts and the couple moment due to the distributions of gas pressure are generated simultaneously, and by the total balance of these both kinds of couple moments, the cam angle is adjusted so as to become an arbitrary predetermined angle and the displacement of the compressor is controlled at a desired displacement.

[0007] Where, the meanings of respective symbols in Fig. 14 are as follows.

Pc: crank chamber pressure (gas pressure to be controlled)
Ps: suction pressure
Pd: discharge pressure
Ap: area of piston (cylinder bore)
L1: distance from momentary rotation center of cam angle change to line of action of pressure applied to piston in compression stroke
L2: distance from momentary rotation center of cam angle change to line of action of pressure applied to piston in suction stroke
M1: moment in a direction for increasing cam angle
M2: moment in a direction for decreasing cam angle

$$M1 = Pc \cdot Ap \cdot L1 + Ps \cdot Ap \cdot L2$$

$$M2 = -Pd \cdot Ap \cdot L1 - Pc \cdot Ap \cdot L2$$

$$\begin{aligned} M1+M2 &= Pc \cdot Ap \cdot L1 + Ps \cdot Ap \cdot L2 - Pd \cdot Ap \cdot L1 - Pc \cdot Ap \cdot L2 \\ &= Pc(Ap \cdot L1 - Ap \cdot L2) + Ps \cdot Ap \cdot L2 - Pd \cdot Ap \cdot L1 \\ &\doteqdot (-Pc+Ps)Ap \cdot L2 \text{ (in case of } L1 \doteqdot 0) \end{aligned}$$

In the above-described conventional structure, L1 is set to be small so that a load due to the discharge pressure does not influence the control of the swash plate cam angle. Therefore, if a differential pressure between the crank chamber pressure and the suction pressure is adjusted, the cam angle can be controlled so as to be balanced with the couple moment due to the rotational and reciprocal movements of the respective parts shown in Fig. 13. Further, with respect to M1 and M2 shown in Fig. 14, actually M1 and M2 are calculated for all pistons.

[0008] In the variable displacement compressor having such a conventional structure, because a control gas with relatively high temperature and high pressure, which is reduced in pressure from the discharge pressure, is introduced into the crank chamber, the durability for rotational and drive parts and for a seal portion is disadvantageous. Further, in order to solve or reduce a noise problem originating from pulsation of suction or discharge, etc., there is a case where a pulsation reducing element such as a throttle valve or a muffler is incorporated into a cylinder head, but if do so, the design freedom on layout in relation to a control valve or a refrigerant interruption valve required for a clutchless type becomes low. Furthermore, because the control of the displacement (swash plate tilt angle) is performed basically by controlling the gas pressure of the crank chamber by adjusting the pressure difference between the crank chamber pressure and the discharge chamber pressure or between the crank chamber pressure and the suction chamber pressure by changing the opening degree of the control valve, namely, because the control of the displacement (swash plate tilt angle) is performed only by control of gas pressure, there is a limit in control accuracy as compared with the control in the present invention described later which utilizes one to one mechanical correspondence between the axial position of an axial movement member and the tilt angle of the swash plate.

[0009] As a technology relating to the present invention, a structure of a compressor is known wherein, in order to aim cooling and lubrication of respective sliding portions and reduction of pulsation of suction and in order to suppress elevation of discharge temperature, a suction hole for refrigerant gas connected to an external circuit is opened to a crank chamber, and suction gas is introduced from the crank chamber into a suction chamber formed in a cylinder head through a communication path formed in a cylinder block (for example, Patent documents 2 and 3). In these conventional technologies, however, an axial movement member, a structure for applying the pressure of a crank chamber at one end side of the axial movement member and an intermediate pressure between the discharge pressure and the suction pressure at the other end side, and a structure for controlling the intermediate pressure, or the technical concepts of these structures in the present invention described later are not disclosed and suggested, and therefore, the control such as one in the present invention cannot be carried out.

Prior art documents

Patent documents

[0010]

Patent document 1: JP-A-2008-138637
Patent document 2: JP-A-8-189464
Patent document 3: JP-A-9-273483

Summary of the Invention

Problems to be solved by the Invention

[0011] Accordingly, an object of the present invention is to provide a variable displacement compressor excellent in performance and property which can achieve to improve the performance of the compressor such as reduction of pulsation and improvement of durability and resistance to pressure and which can control the tilt angle of a swash plate at a target tilt angle more smoothly and precisely via an axial movement member.

Means for solving the Problems

[0012] To achieve the above objects, a variable displacement compressor according to the present invention has a cylinder head in which a suction chamber and a discharge chamber are formed, a cylinder block having a cylinder bore into which a piston is inserted at a condition capable of being reciprocated, a crank chamber formed by the cylinder block and a front housing, a swash plate which is disposed in the crank chamber and which is rotated with a main shaft and is supported so that a tilt angle thereof can be changed relative to the main shaft, and a movement conversion mechanism for converting rotational movement of the swash plate to reciprocating movement of the piston, and is **characterized in that** a suction path for intake of a suction gas into the compressor is formed so as to open into the crank chamber, a communication path for communicating the crank chamber and the suction chamber is provided in the cylinder block, an axial movement member, which can move in a direction along an axis of the main shaft in an essentially one to one correspondence with the tilt angle of the swash plate, is provided around the main shaft, the axial movement member is disposed such that one end is applied with a pressure in the crank chamber and the other end is applied with an intermediate pressure between a pressure in the discharge chamber and a pressure in the suction chamber, and an intermediate pressure control mechanism which can control the intermediate pressure is also provided.

[0013] In such a variable displacement compressor according to the present invention, the suction path for intake of suction gas into the compressor from outside is not directly opened into the suction chamber formed in the cylinder head, but first it is opened into the crank chamber, and the suction gas introduced into the crank chamber is introduced into the suction chamber through the communication path provided in the cylinder block. Therefore, because the crank chamber great in capacity becomes a suction chamber relative to an external circuit, noise originating from pulsation of suction can be prevented or reduced. Further, by this structure, since it becomes possible to reduce the capacity of the suction chamber formed in the cylinder head, by an amount of the reduction, the capacity of the discharge chamber can be increased, noise originating from pulsation of discharge can also be prevented or reduced. Further, because the inside of the crank chamber becomes a suction gas atmosphere and the temperature and the pressure are reduced, the durability of a seal member or a drive part for the main shaft can be improved, and the pressure resistance of a housing part forming the crank chamber can be relatively improved. If the pressure resistance of a housing part, particularly, a front housing, is improved, lightening in weight due to thinning and the like becomes possible. Then, the pressure in the crank chamber and the intermediate pressure controlled by the intermediate pressure control mechanism are applied to the respective ends of the axial movement member which can move in a direction along the axis of the main shaft in an essentially one to one correspondence with the tilt angle of the swash plate, by this the axial position of the axial movement member is controlled precisely, and via the positional control, the tilt angle of the swash plate and the displacement of the compressor are controlled precisely. Therefore, since it becomes a control of the displacement (tilt angle of the swash plate) via the positional control in an axial direction of the axial movement member as compared with the conventional control of the displacement (tilt angle of the swash plate) performed only by the total balance of the couple moment due to the rotational and reciprocal movements of the respective parts and the couple moment due to the distributions of gas pressure, the stability of the control can be improved, and it becomes possible to improve the precision of control. This positional control in an axial direction of the axial movement member is performed in accordance with a pressure difference between the gas pressure of the crank chamber side (suction gas pressure) applied to one end of the axial movement member and an intermediate pressure between the discharge gas pressure and the suction gas pressure applied to the other end, and because this intermediate pressure cannot be made lower than the suction gas pressure applied to the opposite side, only by the gas pressures applied to both ends of this axial movement member, the axial movement member can be controlled only in a direction for increasing the cam angle (tilt angle of the swash plate). However, because in practice the cam angle (tilt angle of the swash plate) is decided by the total balance of the couple moment generated by the gas pressures in the respective spaces in the compressor which act in the cam angle increasing/decreasing direction and the couple moment generated by the rotational and reciprocal movements of the respective parts in the compressor, for example, by setting the cam profile so that an adequate couple moment in a direction for decreasing the cam angle is generated by the operation of discharge gas to the piston, by setting so that the total balance of couple moments generated by the rotational and reciprocal movements of the respective parts in the compressor becomes one in a direction for decreasing the cam angle (a direction for decreasing the tilt angle of the swash plate, namely, a direction for decreasing the displacement) at every cam angle (tilt angle of the swash plate), or by employing both of these, the positional control in the axial direction becomes possible only by the control of the above-described intermediate pressure, via this control a precise and smooth displacement control becomes possible, and the starting shock particularly at a high-speed condition can be relieved, thereby achieving a smooth starting property. Further, it is structured so that the total balance of the couple moments generated by the rotational and reciprocal movements of the respective parts in the compressor acts in a direction for decreasing the cam angle in every region for changing the cam angle, for example, in case of a clutchless type drive force transmission system, maintenance of compressor operation off mode (namely, a mode for keeping the tilt angle of the swash plate at a minimum angle) becomes possible without performing to increase the pressure in the crank chamber, etc., the circulation amount of refrigerant in the compressor at the time of compressor operation off mode decreases, and by the amount of the decrease, it becomes possible to reduce the consumption power. Namely, in case of clutchless type, because the rotational parts such as the swash plate kept at a minimum angle at the time of compressor operation off mode are being rotated as they are, by reducing the consumption power at that time, the total consumption power of the compressor is also reduced.

[0014] In the above-described variable displacement compressor according to the present invention, as the route of the above-described suction path formed so as to open into the crank chamber, various embodiments can be employed as follows. For example, a structure can be employed wherein the suction path is formed in the front housing, and the suction gas is taken directly into the crank chamber from an external circuit. Alternatively, a structure can also be employed wherein the suction path is formed from the cylinder block to the front housing, and the suction gas from an external circuit is once taken into a cylinder block portion and therefrom taken into the crank chamber through a front housing portion. Alternatively, a structure can also be employed wherein the suction path is formed from the cylinder head to the front housing through the cylinder block (by positioning the cylinder block therebetween), and the suction gas from an external circuit is once taken into a cylinder head portion (a portion different from the suction chamber formed in the cylinder head) and therefrom taken into the crank chamber through a cylinder block portion and a front housing portion.

[0015] Further, with respect to the structure where pressures are applied to both ends of the above-described axial movement member in the present invention, basically it is necessary that the pressures at both ends of the member are sealed from each other. For this, a structure is preferred wherein an intermediate pressure chamber controlled at the above-described intermediate pressure is formed on the other end of the axial movement member, and the intermediate pressure chamber is sealed against the crank chamber.

[0016] In such a structure provided with the intermediate pressure chamber, as the above-described intermediate pressure control mechanism, various embodiments can be employed as follows. For example, a structure can be employed wherein the intermediate pressure control mechanism has a communication path (A) between the discharge chamber and the intermediate pressure chamber, a control valve provided in the communication path (A) and capable of controlling pressure reduction from a pressure in the discharge chamber to a predetermined intermediate pressure, a communication path (B) between the intermediate pressure chamber and the suction chamber, and a throttle provided in the communication path (B). Alternatively, a structure can also be employed wherein the intermediate pressure control mechanism has a communication path between the discharge chamber and the intermediate pressure chamber, a communication path between the intermediate pressure chamber and the suction chamber, and a control valve which is provided in both communication paths and which can control pressure reduction from a pressure in the discharge chamber to a predetermined intermediate pressure and can control a degree of throttling for a gas flow from the intermediate pressure chamber to the suction chamber. Alternatively, a structure can also be employed wherein the intermediate pressure control mechanism has a communication path (A) between the discharge chamber and the intermediate pressure chamber, a throttle provided in the communication path (A), a communication path (B) between the intermediate pressure chamber and the suction chamber, and a control valve provided in the communication path (B) and capable of controlling pressure reduction to a predetermined intermediate pressure in the intermediate pressure chamber. In case of the embodiment where the intermediate pressure control mechanism is provided in the communication path between the discharge chamber and the intermediate pressure chamber, the seal member provided at the other end side of the axial movement member may be a seal member allowing a leakage from the intermediate pressure chamber to the crank chamber corresponding to the amount of gas flow passing through the throttle present between the intermediate pressure chamber and the suction chamber, and in this case, it is possible to omit the communication path from the intermediate pressure chamber to the suction chamber and the throttle in the communication path.

[0017] Further, in the present invention, the above-described movement conversion mechanism can employ various embodiments as follows. For example, a structure can be employed wherein the movement conversion mechanism has a wabble plate in which the rotational movement of the swash plate is converted into a wabble movement of the wabble plate and which transmits the wabble movement to the piston via a connecting rod and makes the piston reciprocate, and a rotation preventing mechanism of the wabble plate. Namely, it is structured as a so-called wabble plate type variable displacement compressor.

[0018] In case where it is structured to such a wabble plate type variable displacement compressor, the structure described in Patent document 1 that is a previous application by the applicant of the present application can be employed. Namely, a structure can be employed wherein the above-described rotation preventing mechanism of the wabble plate comprises (a) an inner ring provided in a housing movably in an axial direction although rotation is prevented, and having a plurality of guide grooves for guiding a plurality of balls provided for power transmission, (b) an outer ring having a plurality of guide grooves for guiding the balls at positions opposing respective guide grooves of the inner ring, connected with the wabble plate at an outer circumference and supported at a condition capable of wabbling together with the wabble plate, and (c) a plurality of balls held by the guide grooves formed in the inner ring and the outer ring at a condition of opposing each other and performing power transmission by being compressed between the guide grooves, and in this case, the inner ring may be formed as the above-described axial movement member.

[0019] Further, in this case, as described in the aforementioned Patent document 1, a structure may be employed wherein the above-described rotation preventing mechanism of the wabble plate further comprises (d) a sleeve functioning as a wabble central member of the wabble movement of the wabble plate, provided on the main shaft to rotate relatively to the main shaft and to move in an axial direction, and engaged with the inner ring movably in an axial direction together with the inner ring, and the outer ring is supported on the sleeve wabblingly.

[0020] Alternatively, in the variable displacement compressor according to the present invention, except employing the structure of the above-described wabble plate type variable displacement compressor, for example, an embodiment may be employed wherein the above-described movement conversion mechanism is formed as a mechanism for conversion into reciprocal movement of the piston via a pair of shoes slid on both surfaces of an outer circumference of the swash plate.

[0021] Further, in the variable displacement compressor according to the present invention, in order to be able to control the tilt angle of the swash plate at a target tilt angle efficiently, precisely and quickly, it is preferred to add a device to a cam mechanism for changing the tilt angle of the swash plate. For example, it is preferred that the tilt angle of the swash plate can be changed through a cam mechanism interposed between the main shaft and the swash plate, and a cam profile of the cam mechanism is set so that a momentary rotation center of the swash plate is given at a position at which a load due to a compression reactive force of at least one piston among a plurality of pistons present in a compression stroke operates as a couple moment acting in a direction for decreasing displacement relatively to the swash plate. A concrete example of this mechanism will be explained in detail in the embodiment of the present invention described later.

[0022] Further, such a mechanism can be realized as follows. For example, it can be realized by a mechanism wherein the above-described cam mechanism comprises a sliding engagement mechanism formed by a slot formed on one of an arm extending from main shaft side and an arm extending from swash plate side and a pin provided on the other, and the above-described cam profile is set by forming a shape of the slot as an S-shape.

[0023] Further, in the variable displacement compressor according to the present invention, it is preferred that respective parts are set so that a total balance of a couple moment generated in a tilt angle changing plane of the swash plate by at least rotational and reciprocal movement of the respective parts becomes one in a direction for decreasing tilt angle in every tilt angle of the swash plate. In such a structure, since the total balance of the couple moment of the swash plate due to the rotational and reciprocal movements of respective parts always acts in a direction for decreasing the tilt angle of the swash plate, namely, since it always acts in desired one direction, as long as the aforementioned intermediate pressure applied to the other end of the axial movement member is controlled, it becomes possible to control the tilt angle of the swash plate at a target tilt angle easily and precisely. In other words, as aforementioned, because the intermediate pressure applied to the other end side of the axial movement member cannot be made lower than the suction pressure applied to the opposite side, only by the gas pressures applied to both end sides of the axial movement member, the axial movement member can be operated only in a direction for increasing the cam angle (the tilt angle of the swash plate). However, if it is set so that the total balance of the couple moment of the swash plate due to the rotational and reciprocal movements of the respective parts always acts in a direction for decreasing the tilt angle of the swash plate, by the control of the intermediate pressure, the cam angle (the tilt angle of the swash plate) can be easily controlled at an arbitrary desired angle. Further, because a couple moment for decreasing the tilt angle always acts to the swash plate, for example, in case where the compressor operation off mode is required to be kept, etc., only by driving and rotating the compressor the swash plate is naturally changed in angle in a direction of a minimum tilt angle, and after changed to the minimum tilt angle, the swash plate is maintained at the minimum tilt angle.

[0024] In this case, it is also possible to employ a structure wherein a spring for urging at least the swash plate in a direction for decreasing the tilt angle is further provided, and a total balance of a couple moment generated in a tilt angle changing plane of the swash plate by the rotational and reciprocal movement including by an urging force of the spring is set so as to become one in a direction for decreasing the tilt angle in every tilt angle of the swash plate. As described later, this embodiment is effective for a case where the swash plate to be changed in tilt angle is required to be always pushed in a direction for decreasing the tilt angle regardless of change of the tilt angle, etc. For example, even in case where the above-described axial movement member is not mechanically connected to the swash plate or a swash plate supporting member, it becomes possible to always push the central portion of the swash plate or the swash plate supporting member and the axial movement member to each other in an axial direction and to always move both members integrally in the axial direction, and whereby, it becomes possible that the axial position of the axial movement member is always in one to one correspondence with the tilt angle of the swash plate precisely.

Effect according to the Invention

[0025] Thus, in the variable displacement compressor according to the present invention, by the structure where the suction gas is taken into the crank chamber through the suction path opening into the crank chamber, noise originating from pulsation of suction can be prevented or reduced by functioning the crank chamber with a great capacity as a suction chamber. Further, because a suction throttle valve is omitted, the design freedom on layout of cylinder head can be increased. Further, by the structure where the suction gas is introduced into the suction chamber formed in the cylinder head from the crank chamber through the communication path, because it becomes possible to reduce the capacity of the suction chamber, and by the amount of the reduction, the capacity of the discharge chamber can be increased, noise originating from pulsation of discharge can also be prevented or reduced. Further, because the temperature and pressure in the crank chamber can be reduced, the durability of the respective drive parts and the pressure resistance of a housing part can be improved, and it becomes possible to thin the housing part and make the whole of the compressor small and light in weight. Further, by the structure where the pressure in the crank chamber and the intermediate pressure controlled by the intermediate pressure control mechanism are applied to the respective ends of the axial movement member and the axial position of the axial movement member is controlled precisely, through the position control, it becomes possible to control the tilt angle of the swash plate and the displacement of the compressor stably and precisely. In particular, if it is set so that the total balance of the couple moment generated by the rotational and reciprocal movements of the respective parts in the compressor is always directed in a direction for decreasing the cam angle (a direction for decreasing the tilt angle of the swash plate, namely, a direction for decreasing the displacement), through the axial position control of the axial movement member controlled only by the control of the intermediate pressure, it becomes possible to perform the displacement control easily and more smoothly, and in particular, a starting shock at a high-speed driving time and the like can be relieved, and a smooth starting property can be obtained. Furthermore, by setting such a total balance of couple moment, it becomes possible to reduce the consumption power in case of a clutchless type compressor.

Brief explanation of the drawings

[0026]

[Fig. 1] Fig. 1 is a vertical sectional view of a variable displacement compressor according to a first embodiment of the present invention showing a state at the time of a maximum tilt angle of a swash plate.

[Fig. 2] Fig. 2 is an enlarged partial sectional view of the variable displacement compressor depicted in Fig. 1.

[Fig. 3] Fig. 3 is a vertical sectional view of the variable displacement compressor depicted in Fig. 1 showing a state at the time of a minimum tilt angle of the swash plate.

[Fig. 4] Fig. 4 is an enlarged partial sectional view of the variable displacement compressor depicted in Fig. 3.

[Fig. 5] Fig. 5 is a diagram indicating a relationship between a cam angle and a couple moment, showing a balance of the couple moments due to rotational and reciprocal movements of respective parts of the variable displacement compressor depicted in Fig. 1.

[Fig. 6] Fig. 6 is an explanation diagram showing a balance of a couple moment due to gas pressures of the variable displacement compressor depicted in Fig. 1.

[Fig. 7] Fig. 7 is a partial vertical sectional view of a variable displacement compressor according to a second embodiment of the present invention.

[Fig. 8] Fig. 8 is a vertical sectional view of a variable displacement compressor according to a third embodiment of the present invention.

[Fig. 9] Fig. 9 is a vertical sectional view of a variable displacement compressor according to a fourth embodiment of the present invention.

[Fig. 10] Fig. 10 is a vertical sectional view of a variable displacement compressor according to a fifth embodiment of the present invention.

[Fig. 11] Fig. 11 is a vertical sectional view of a conventional variable displacement compressor at the time of a maximum tilt angle of a swash plate.

[Fig. 12] Fig. 12 is a vertical sectional view of the variable displacement compressor depicted in Fig. 11 at the time of a minimum tilt angle of the swash plate.

[Fig. 13] Fig. 13 is a diagram indicating a relationship between a cam angle and a couple moment, showing a balance of the couple moments due to rotational and reciprocal movements of respective parts of the variable displacement compressor depicted in Fig. 11.

[Fig. 14] Fig. 14 is an explanation diagram showing a balance of a couple moment due to gas pressures of the variable displacement compressor depicted in Fig. 11.

Embodiments for carrying out the Invention

[0027] Hereinafter, concrete embodiments of the present invention will be explained referring to figures.

Figs. 1 to 6 show a variable displacement compressor according to a first embodiment of the present invention. Fig. 1 shows a state at the time of a maximum displacement (a maximum cam angle [a maximum swash plate angle]) of a variable displacement compressor 1, and Fig. 3 shows a state at the time of a minimum displacement (a minimum cam angle [a minimum swash plate angle]). In Fig. 1, a main shaft 5 is inserted into a crank chamber 4 formed by a front housing 2 and a cylinder block 3, relatively to main shaft 5, provided is a rotor 6 which is fixed to main shaft 5 and rotated integrally with main shaft 5, and disposed is a swash plate 7 which can be changed in its tilt angle relative to main shaft 5 and which can be rotated integrally with main shaft 5. Between rotor 6 and swash plate 7, provided is a hinge mechanism 12 forming a sliding mechanism wherein an arm 8 extending from rotor 6 side (main shaft 5 side) and an arm 9 extending from swash plate 7 side are provided, a slot 10 is provided on arm 9 side and a pin 11 engaging slot 10 is provided on arm 8 side, and via the hinge mechanism 12, swash plate 7 is provided at a condition capable of being changed in tilt angle and being rotated integrally with main shaft 5. At a side of swash plate 7 opposite hinge mechanism 12 side, a counter weight 13 is embedded or attached in order to achieve a rotational balance between swash plate 7 and the rotation mechanism including hinge mechanism 12. The sliding engagement mechanism between slot 10 and pin 11 in this hinge mechanism 12 forms a cam mechanism for changing the tilt angle of swash plate 7, and in this embodiment, slot 10 is formed as an S shape in order to set the cam profile of the cam mechanism due to hinge mechanism 12, as described later in detail using Fig. 5, so that a momentary rotation center of swash plate 7 is given at a position at which a load due to a compression reactive force of at least one piston among a plurality of pistons present in a compression stroke operates as a couple moment acting in a direction for decreasing displacement relatively to swash plate 7. Further, in this embodiment, a suction port 14 is provided directly on front housing 2, and a suction path 15 for taking suction gas from outside into crank chamber 4 is formed only on front housing 2.

[0028] In this embodiment, formed is a wabble plate type variable displacement compressor 1 in which provided is a wabble plate 18 which is free to rotate relatively to swash plate 7 via bearings 16, 17 and whose wabble movement is only allowed at a condition prevented with its rotation. The rotational movement of swash plate 7 is converted into the wabble movement of wabble plate 18, and the wabble movement is the reciprocal movement of a piston 21 which is inserted into a cylinder bore 20 at a condition free to be reciprocated, through a connecting rod 19. Rotation preventing mechanism 22 of wabble plate 18 is formed as a mechanism comprising (i) an inner ring 27 provided movably in an axial direction although the rotation is prevented through a spline engagement mechanism 24 formed between it and a center hole 23 of cylinder block 3, provided free to be rotated relatively to main shaft 5 via a bearing 48, and having a plurality of guide grooves 26 for guiding a plurality of balls 25 provided for power transmission, (ii) a sleeve 28 functioning as a wabble central member of the wabble movement of wabble plate 18, provided at a condition capable of rotating and moving in an axial direction relatively to main shaft 5, and engaged with inner ring 27 movably in an axial direction together with inner ring 27, (iii) an outer ring 30 having a plurality of guide grooves 29 for guiding balls 25 at positions opposing respective guide grooves 26 of inner ring 27, supported on sleeve 28 wabblingly, and supporting wabble plate 18 fixedly on its outer circumference, and (iv) a plurality of balls 25 held by guide grooves 26, 29 formed in inner ring 27 and outer ring 30 at a condition of opposing each other and performing power transmission by being compressed between the guide grooves 26, 29. Inner ring 27 in this rotation preventing mechanism 22 of wabble plate 18 forms an axial movement member according to the present invention, which can move in a direction along an axis of main shaft 5 in an essentially one to one correspondence with the tilt angle of swash plate 7.

[0029] In a cylinder head 31, a suction chamber 32 is formed at the radially outside position and a discharge chamber 33 is formed at the radially inside position, respectively. This disposition may be reverse. The suction gas into the compressor is, first, taken into crank chamber 4 from suction port 14 through suction path 15, from crank chamber 4, it is introduced into suction chamber 32 through a communication path 34 formed in cylinder block 3, and therefrom, it is taken into cylinder bore 20 to be served to the compression stroke due to piston 21. The gas compressed by piston 21 in cylinder bore 20 is discharged into discharge chamber 33, and in the embodiment shown in the figure, therefrom, it is sent to an external circuit through a discharge interruption valve 35 and a discharge port 36.

[0030] The gas pressure (Ps) of crank chamber 4 side is applied to one end of the above-described inner ring 27 as the axial movement member, and to the other end, an intermediate pressure (Pm) between the pressure (Pd) in discharge chamber 33 and the pressure (Ps) in suction chamber 32. At the other end side of this inner ring 27, formed is an intermediate pressure chamber 38 sealed by seal members 37 and 45 relatively to crank chamber 4 side, and the pressure in intermediate pressure chamber 38 is controlled at the above-described predetermined intermediate pressure (Pm) by an intermediate pressure control mechanism 39.

[0031] This intermediate pressure control mechanism 39 is formed as follows in this embodiment.

A communication path 40 is provided between discharge chamber 33 and intermediate pressure chamber 38, in the communication path 40 disposed is a control valve 41 capable of controlling pressure reduction from the pressure (Pd) in discharge chamber 33 to a predetermined intermediate pressure (Pm), a communication path 42 is provided between intermediate pressure chamber 38 and suction chamber 32, and in the communication path 42, formed is an throttle 43 (orifice) capable of reducing the pressure from intermediate pressure (Pm) to the pressure (Ps) in suction chamber 32.

[0032] The above-described intermediate pressure chamber 38 is formed between the rear end portion (the other end portion) of inner ring 27 and a valve plate 44 at the rear end portion of main shaft 5, and this intermediate pressure chamber 38 becomes a condition shown in Fig. 2 in correspondence with the condition shown in Fig. 1, and is interposed between main shaft 5 and inner ring 27, both members are supported at a condition free to be relatively rotated and inner ring 27 is supported movably in an axial direction relatively to main shaft 5. It is sealed in pressure relatively to crank chamber 4 side by the aforementioned seal members 37 and 45. As shown in Fig. 2, to inner ring 27 as an axial movement member, an axial load is generated by a pressure difference between the intermediate pressure Pm applied to an annular pressure receiving surface 46 surrounded by seal members 37, 45 and the pressure of crank chamber 4 side applied to the opposite side. Intermediate pressure chamber 38 becomes a condition shown in Fig. 4 in correspondence with the condition shown in Fig. 3, seal members 37, 45 are sealed slidably in an axial direction, and at the time of minimum cam angle (minimum tilt angle of swash plate), accompanying with the slide movement of inner ring 27, the capacity of intermediate pressure chamber 38 is decreased.

[0033] Where, although a clutchless type compressor, in which a rotational drive force from a power source (not shown in the figure) is transmitted directly to main shaft 5 via a pulley 47, is exemplified in the above-described embodiment, it is possible to form it as a clutch type compressor in which therebetween a clutch (in particular, an electromagnetic clutch) (not shown in the figure) capable of switching between the power transmission interrupted condition and the power transmission condition is interposed.

[0034] In variable displacement compressor 1 thus constructed, suction path 15 taking the suction gas from outside into compressor 1 is formed only in front housing 2, the suction gas taken through suction path 15 is first sucked into crank chamber 4, and therefrom, introduced into suction chamber 32 through communication path 34. Therefore, because crank chamber 4 having a large capacity becomes a suction chamber relative to an external circuit, noise originating from suction pulsation is prevented or reduced. Further, because a suction throttle valve can be omitted, the design freedom on layout of cylinder head 31 can be increased. Further, since the capacity of suction chamber 32 formed in cylinder head 31 may be small as compared with a conventional case where the suction gas is taken directly into a suction chamber and by the amount the capacity of discharge chamber 33 can be increased even if the size of cylinder head 31 is same, noise originating from discharge pulsation can also be prevented or reduced. Further, because the inside of crank chamber 4 becomes a suction gas atmosphere and the temperature and pressure thereof can be reduced as compared with those in a conventional structure, the durability of respective drive parts including rotor 6, bearings supporting it, hinge mechanism 12, etc. can be improved, and further, the pressure resistance of housing parts (in particular, front housing 2) forming crank chamber 4 may be improved relatively. In particular, if the pressure resistance of front housing 2 is improved, it can be made thinner, and can be made small-sized and light in weight.

[0035] Further, since the tilt angle of swash plate 7 and the displacement of compressor 1 can be controlled via the positional control of the axial movement member (inner ring 27) movable in a direction along the axis of main shaft 5 in an essentially one to one correspondence with the tilt angle of swash plate 7, it becomes possible to depend the control of the tilt angle of swash plate 7 on the mechanical accuracy, and it becomes possible to improve the control precision greatly. In this positional control of the axial movement member (inner ring 27), the pressure in crank chamber 4 and the pressure in intermediate pressure chamber 32 controlled by intermediate pressure control mechanism 39 are applied to the respective ends of the axial movement member, by the pressure difference therebetween the position in the axial direction of the axial movement member is controlled precisely, and via the positional control of the axial movement member, the tilt angle of swash plate 7 and the displacement of compressor 1 are controlled stably.

[0036] Further, in the above-described control of the tilt angle of swash plate 7, by setting the following total balance of couple moment, a more stable and desirable control can be achieved, and more concretely, a more smooth displacement control becomes possible, and in particular, a starting shock at a high-speed condition, etc. can be relieved and a smooth starting property can be obtained.

[0037] With respect to couple moments generated by the rotational and reciprocal movements of the respective parts in compressor 1, they will be explained referring to Figs. 5 and 6. Fig. 5 shows a balance of couple moments due to rotational and reciprocal movements of respective parts in compressor 1, and Fig. 6 shows a balance of a couple moment due to gas pressures applied to respective parts in compressor 1. Meanings of respective symbols in Fig. 6 are as follows.

Pm: intermediate pressure (control pressure applied to the rear end portion side of inner ring 27 as the axial movement member)
Ps: suction pressure
Pd: discharge pressure
Ap: area of piston (cylinder bore)
As: pressure receiving area of inner ring 27 as the axial movement member
L1: distance from momentary rotation center (C) of swash plate 7 at the time of cam angle change in the cam mechanism (hinge mechanism 12) to line of action of pressure applied to piston in compression stroke
L2: distance from momentary rotation center (C) of swash plate 7 at the time of cam angle change to line of action of pressure applied to piston in suction stroke L3: distance from momentary rotation center (C) of swash plate 7 at the time of cam angle change to line of action of pressure applied to inner ring 27
M1: moment in a direction for increasing cam angle (tilt angle of swash plate)
M2: moment in a direction for decreasing cam angle (tilt angle of swash plate)

$$M1=Ps\cdot Ap\cdot L1+Pm\cdot As\cdot L3+Ps\cdot Ap\cdot L2$$

$$M2=-Pd\cdot Ap\cdot L1-Ps\cdot As\cdot L3-Ps\cdot Ap\cdot L2$$

$$\begin{aligned} M1+M2 &= Ps\cdot Ap\cdot L1+Pm\cdot As\cdot L3+Ps\cdot Ap\cdot L2-Pd\cdot Ap\cdot L1-Ps\cdot As\cdot L3-Ps\cdot Ap\cdot L2 \\ &= (Ps-Pd)Ap\cdot L1+(Pm-Ps)As\cdot L3 \\ &\fallingdotseq (Ps-Pd+Pm-Ps)As\cdot L3 \text{ (in case of } Ap\fallingdotseq As,\ L1\fallingdotseq L3) \\ &= (Pm-Pd)As\cdot L3 \end{aligned}$$

With respect to M1 and M2 shown in Fig. 6, actually M1 and M2 are calculated for all pistons. Further, it is preferred that

Ap and As, and L1 and L3, are set so as to become adequate relationships, respectively.

[0038] Where, the moment of piston 21 in suction stroke is cancelled because the pressures at it front and rear sides are same pressure (Ps). Further, the cam angle of the swash plate can be controlled optimum by controlling the pressure difference between Pm and Ps at a condition where the position of momentary rotation center (C) is set at an adequate position (namely, the cam profile in the cam mechanism is set adequately) and the pressure receiving area of inner ring 27 is set at an adequate size. More accurately, by the pressure difference between Pm and Ps, the moment of the system including inner ring 27 is decided, and the balance of respective moments ia taken. At that time, in order that the moment due to the pressure difference between Pm and Ps operates effectively, it is preferred to intentionally set the above-described L1 large, and therethrough, it becomes possible to realize the total balance of couple moments described below. It becomes possible to intentionally set the above-described L1 large by forming slot 10 in cam mechanism 12 as an S-shape as shown in Fig. 6.

[0039] The balance of the couple moments due to the rotational and reciprocal movements in the above-described compressor 1 is preferably set so as to become the property shown in Fig. 5. Namely, since the balance of the couple moment due to the gas pressures in the above-described compressor 1 becomes a moment for urging in a direction for increasing the cam angle when the intermediate pressure Pm is increased, as the balance of the couple moments due to the rotational and reciprocal movements of respective parts, as shown in Fig. 5, it is preferably set so as to be urged in a direction for decreasing the cam angle at every cam angle. Namely, in Fig. 5, even at a minimum cam angle, it is set so that the total couple moment always acts in a direction for decreasing the cam angle. By such a setting, a more desirable, stable and precise displacement control is realized. Further, counter weight 13 also can contribute this desirable setting.

[0040] Namely, for example, in Fig. 6, because moment M2 becomes small at such a low load condition where Pd becomes low, for example, it becomes difficult to maintain the off mode. If the property shown in Fig. 5 is set at such a time, because the couple moment in a direction for decreasing the cam angle different from the couple moment due to the gas pressure always operates, the maintenance of off mode and the like becomes easy. Further, in Fig. 6, in case where the momentary center is present at a position far from the center of the main shaft as in a conventional structure (as shown in Fig. 14), because L1 in Fig. 6 is small, moment M2 due to Pd in a direction for decreasing the cam angle does not work. With respect to the axial movement member, since Pm applied to the rear-side surface cannot be made smaller than Ps applied to the pressure receiving surface at the opposite side, it can be operated only in a direction for increasing the cam angle, and if the cam angle is once increased, it cannot be decreased. Therefore, in case where the couple moment due to gas pressure has a property wherein moment M2 in a direction for decreasing the cam angle does not work as described above, it is necessary to set the couple moments generated by the rotational and reciprocal movements (or using reducing spring 109 together) at the property shown in Fig. 5 and to always ensure a couple moment in a direction for decreasing the cam angle. However, because the property shown in Fig. 5 is small in operation when the rotational speed of the compressor is low, at such a time for maintaining off mode, it is necessary to ensure the couple moment in a direction for decreasing the cam angle by another method. In order to achieve this, the property shown in Fig. 6 is preferred.

[0041] Fig. 7 shows a main portion of a variable displacement compressor 51 according to a second embodiment of the present invention. In this embodiment, as compared with the aforementioned first embodiment, the intermediate pressure (Pm) is introduced into intermediate pressure chamber 38 after the discharge gas is controlled by a control valve 52 disposed in communication path 40 from discharge chamber 33 in cylinder head 31 to intermediate pressure chamber 38, and returned from intermediate pressure chamber 38 into suction chamber 32 again through control valve 52 in a communication path 53 from intermediate pressure chamber 38 to suction chamber 32. Namely, the intermediate pressure (Pm) is controlled by the control of control valve 52 for adjusting the introduction amount into intermediate pressure chamber 38 and the relief amount from intermediate pressure chamber 38. The other structures are formed correspondingly to the first embodiment shown in Fig. 1. Also in such a structure, operation and advantage similar to those in the aforementioned first embodiment can be obtained, and further, simplification of the intermediate pressure control mechanism becomes possible.

[0042] Fig. 8 shows a variable displacement compressor 61 according to a third embodiment of the present invention. In this embodiment, as compared with the aforementioned first embodiment, a suction path 62 is formed from a suction port 64 provided in a cylinder head 63 up to cylinder block 65 and front housing 66. Further, a communication path 68 from a crank chamber 67 to suction chamber 32 in cylinder head 63 is formed by utilizing an insertion hole of a fastening bolt 69 for front housing 66, cylinder block 65 and cylinder head 63. Furthermore, the intermediate pressure (Pm) is introduced into intermediate pressure chamber 38 as a pressure reduced from the pressure (Pd) in discharge chamber 33 by a throttle 70, and returned into suction chamber 32 through a control valve 72 disposed in a communication path 71 from intermediate pressure chamber 38 to suction chamber 32. The other structures are formed correspondingly to the first embodiment shown in Fig. 1. Also in such a structure, operation and advantage similar to those in the aforementioned first embodiment can be obtained.

[0043] Fig. 9 shows a variable displacement compressor 81 according to a fourth embodiment of the present invention.

In this embodiment, as compared with the aforementioned first embodiment, in a cylinder head 82, a suction chamber 83 is formed at the radially inner side and a discharge chamber 84 is formed at the radially outer side. A suction path 86 of the suction gas to a crank chamber 85 is formed up to a front housing 90 through a suction port 88 and a suction muffler chamber 89 provided in a cylinder block 87. Further, a communication path 91 from crank chamber 85 to suction chamber 83 in cylinder head 82 is disposed straightly at the radially inner side between cylinder bores 20 in cylinder block 87. Furthermore, the intermediate pressure (Pm) is introduced into intermediate pressure chamber 38 after being controlled a control valve 93 disposed in a communication path 92 from discharge chamber 84 to intermediate pressure chamber 38, and from intermediate pressure chamber 38, returned to suction chamber 32 after being reduced by a throttle 94. The other structures are formed correspondingly to the first embodiment shown in Fig. 1. Also in such a structure, operation and advantage similar to those in the aforementioned first embodiment can be obtained, and further, formation of communication path 91 in cylinder block 87 can be facilitated. Further, since the pulsation of suction damped at suction muffler chamber 89 is further damped at crank chamber 85, the pulsation of suction can be damped more surely. Further, also with respect to the discharge gas, if it may be discharged via a discharge muffler chamber 95 through a discharge interruption valve 96 and a discharge port 97, the pulsation of discharge can also be damped.

[0044] Fig. 10 shows a variable displacement compressor 101 according to a fifth embodiment of the present invention. Wabble plate 18 as shown in the above-described first to fourth embodiments is not provided, and it is structured as a so-called single sided swash plate type variable displacement compressor 101. Namely, the movement conversion mechanism from the rotational movement of a swash plate 102 to the reciprocal movement of a piston 103 is formed as a mechanism for conversion into the reciprocal movement of piston 103 via a pair of shoes 104 slid on both surfaces of the outer circumference of swash plate 102. Because the rotation preventing mechanism for wabble plate 18 as in the above-described first to fourth embodiments is not necessary, instead, as the axial movement member in the present invention, a sleeve 106 is provided around a main shaft 105 movably on main shaft 105 in an axial direction at a condition prevented in rotation by spline mechanism 24. A thrust bearing 107 is provided at the front side of sleeve 106, and it is structured so that the central portion of swash plate 102 can move in an axial direction integrally with sleeve 106 together with the thrust bearing 107 and a collar 108 free to move in an axial direction. At the front side of collar 108, a reducing spring 109 is provided for urging swash plate 102 in a direction for decreasing the tilt angle (namely, in a direction for decreasing the cam angle of the cam mechanism formed by hinge mechanism 12), thereby always urging swash plate 102 in a direction of minimum tilt angle. Although collar 108 and reducing spring 109 rotate integrally with main shaft 105 together with swash plate 102, the swash plate 102 is supported on collar 108 at a condition capable of changing the tilt angle within the tilt angle changing plane. At the other end side of sleeve 106, formed is intermediate pressure chamber 38 similarly to in the first embodiment, and in the intermediate pressure chamber 38, provided is a return spring 110 for urging swash plate 102, which has been changed in angle to the minimum tilt angle side, in a direction for increasing the tilt angle. The other structures are formed correspondingly to the first embodiment shown in Fig. 1, and therefore, the explanation is omitted by labeling the same symbols used in Fig. 1. Even in such a single sided swash plate type variable displacement compressor, operation and advantage similar to those in the first embodiment can be obtained.

[0045] Thus, regardless of a wabble plate type variable displacement compressor or a single sided swash plate type variable displacement compressor, the present invention can be applied.

Industrial Applications of the Invention

[0046] The variable displacement compressor according to the present invention can be applied to any variable displacement compressor having a predetermined axial movement member.

Explanation of symbols

[0047]

1, 51, 61, 81, 101:	variable displacement compressor
2:	front housing
3:	cylinder block
4:	crank chamber
5:	main shaft
6:	rotor
7:	swash plate
8, 9:	arm
10:	slot
11:	pin

12:	hinge mechanism as cam mechanism
13:	counter weight
14:	suction port
15:	suction path
16, 17:	bearing
18:	wabble plate
19:	connecting rod
20:	cylinder bore
21:	piston
22:	rotation preventing mechanism of wabble plate
23:	central hole
24:	spline engagement mechanism
25:	ball
26, 29:	guide groove
27:	inner ring
28:	sleeve
30:	outer ring
31:	cylinder head
32:	suction chamber
33:	discharge chamber
34:	communication path
35:	discharge interruption valve
36:	discharge port
37, 45:	seal member
38:	intermediate pressure chamber
39:	intermediate pressure control mechanism
40, 42:	communication path
41:	control valve
43:	throttle
44:	valve plate
46:	pressure receiving surface
47:	pulley
48:	bearing
52:	control valve
53:	communication path
62:	suction path
63:	cylinder head
64:	suction port
65:	cylinder block
66:	front housing
67:	crank chamber
68:	communication path
69:	fastening bolt
70:	throttle
71:	communication path
72:	control valve
82:	cylinder head
83:	suction chamber
84:	discharge chamber
85:	crank chamber
86:	suction path
87:	cylinder block
88:	suction port
89:	suction muffler chamber
90:	front housing
91, 92:	communication path
93:	control valve
94:	throttle

95:	discharge muffler chamber
96:	discharge interruption valve
97:	discharge port
102:	swash plate
103:	piston
104:	shoe
105:	main shaft
106:	sleeve
107:	thrust bearing
108:	collar
109:	reducing spring
110:	return spring
C:	momentary rotation center
Ps:	suction pressure
Pd:	discharge pressure
Pm:	intermediate pressure

Claims

1. A variable displacement compressor provided with a cylinder head in which a suction chamber and a discharge chamber are formed, a cylinder block having a cylinder bore into which a piston is inserted at a condition capable of being reciprocated, a crank chamber formed by said cylinder block and a front housing, a swash plate which is disposed in said crank chamber and which is rotated with a main shaft and is supported so that a tilt angle thereof can be changed relative to said main shaft, and a movement conversion mechanism for converting rotational movement of said swash plate to reciprocating movement of said piston, **characterized in that** a suction path for intake of a suction gas into said compressor is formed so as to open into said crank chamber, a communication path for communicating said crank chamber and said suction chamber is provided in said cylinder block, an axial movement member, which can move in a direction along an axis of said main shaft in an essentially one to one correspondence with said tilt angle of said swash plate, is provided around said main shaft, said axial movement member is disposed such that one end is applied with a pressure in said crank chamber and the other end is applied with an intermediate pressure between a pressure in said discharge chamber and a pressure in said suction chamber, and an intermediate pressure control mechanism which can control said intermediate pressure is also provided.

2. The variable displacement compressor according to claim 1, wherein said suction path is formed in said front housing.

3. The variable displacement compressor according to claim 1, wherein said suction path is formed from said cylinder block to said front housing.

4. The variable displacement compressor according to claim 1, wherein said suction path is formed from said cylinder head to said front housing through said cylinder block.

5. The variable displacement compressor according to any of claims 1 to 4, wherein an intermediate pressure chamber controlled at said intermediate pressure is formed on said other end of said axial movement member, and said intermediate pressure chamber is sealed against said crank chamber.

6. The variable displacement compressor according to claim 5, wherein said intermediate pressure control mechanism has a communication path (A) between said discharge chamber and said intermediate pressure chamber, a control valve provided in said communication path (A) and capable of controlling pressure reduction from a pressure in said discharge chamber to a predetermined intermediate pressure, a communication path (B) between said intermediate pressure chamber and said suction chamber, and a throttle provided in said communication path (B).

7. The variable displacement compressor according to claim 5, wherein said intermediate pressure control mechanism has a communication path between said discharge chamber and said intermediate pressure chamber, a communication path between said intermediate pressure chamber and said suction chamber, and a control valve which is provided in both said communication paths and which can control pressure reduction from a pressure in said discharge chamber to a predetermined intermediate pressure and can control a degree of throttling for a gas flow from said intermediate pressure chamber to said suction chamber.

8. The variable displacement compressor according to claim 5, wherein said intermediate pressure control mechanism has a communication path (A) between said discharge chamber and said intermediate pressure chamber, a throttle provided in said communication path (A), a communication path (B) between said intermediate pressure chamber and said suction chamber, and a control valve provided in said communication path (B) and capable of controlling pressure reduction to a predetermined intermediate pressure in said intermediate pressure chamber.

9. The variable displacement compressor according to any of claims 1 to 8, wherein said movement conversion mechanism has a wabble plate in which said rotational movement of said swash plate is converted into a wabble movement of said wabble plate and which transmits said wabble movement to said piston via a connecting rod and makes said piston reciprocate, and a rotation preventing mechanism of said wabble plate.

10. The variable displacement compressor according to claim 9, wherein said rotation preventing mechanism of said wabble plate comprises (a) an inner ring provided in a housing movably in an axial direction although rotation is prevented, and having a plurality of guide grooves for guiding a plurality of balls provided for power transmission, (b) an outer ring having a plurality of guide grooves for guiding said balls at positions opposing respective guide grooves of said inner ring, connected with said wabble plate at an outer circumference and supported at a condition capable of wabbling together with said wabble plate, and (c) a plurality of balls held by said guide grooves formed in said inner ring and said outer ring at a condition of opposing each other and performing power transmission by being compressed between said guide grooves, and said inner ring is formed as said axial movement member.

11. The variable displacement compressor according to claim 10, wherein said rotation preventing mechanism of said wabble plate further comprises (d) a sleeve functioning as a wabble central member of said wabble movement of said wabble plate, provided on said main shaft to rotate relatively to said main shaft and to move in an axial direction, and engaged with said inner ring movably in an axial direction together with said inner ring, and said outer ring is supported on said sleeve wabblingly

12. The variable displacement compressor according to any of claims 1 to 8, wherein said movement conversion mechanism is formed as a mechanism for conversion into reciprocal movement of said piston via a pair of shoes slid on both surfaces of an outer circumference of said swash plate.

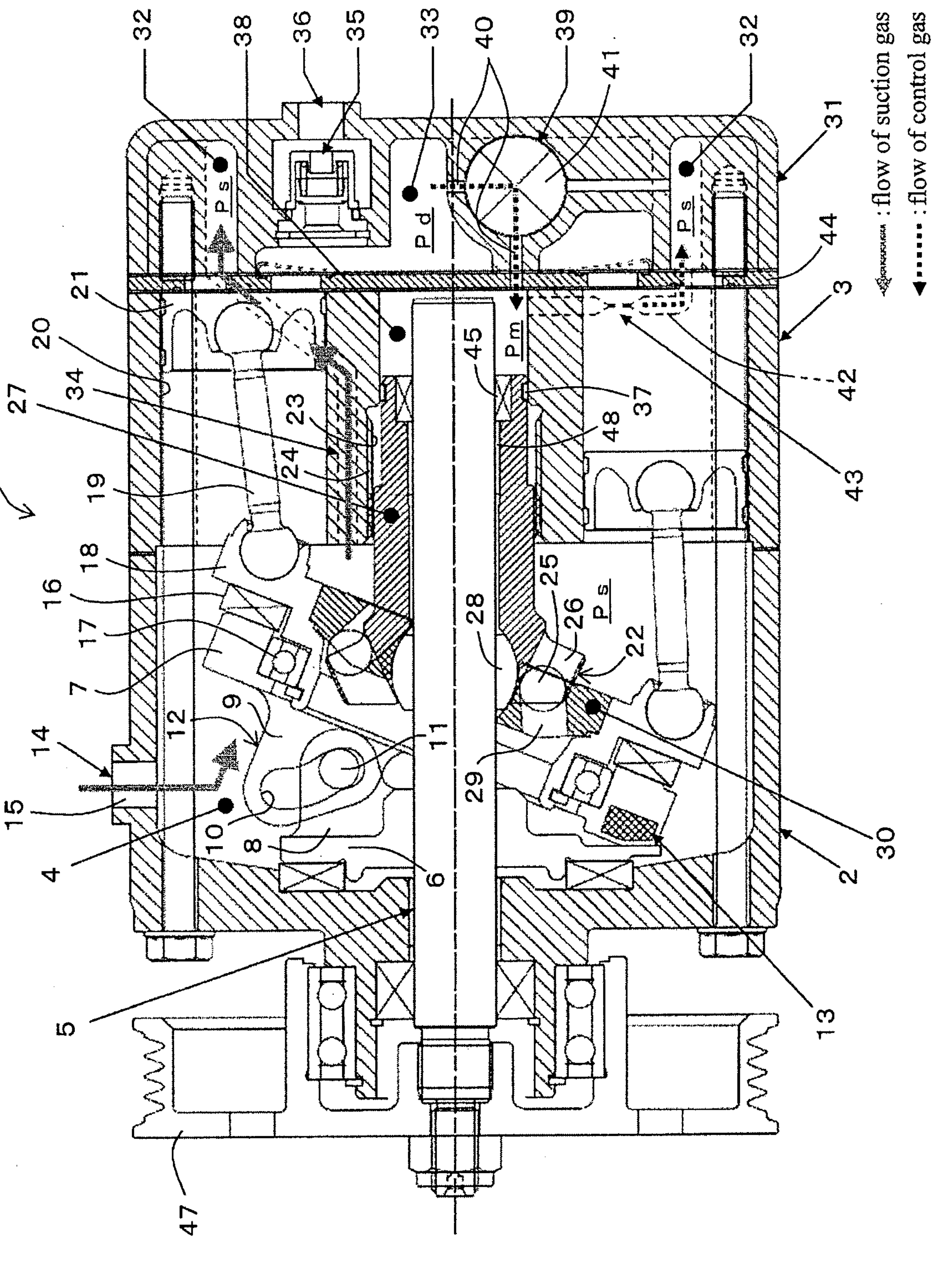
13. The variable displacement compressor according to any of claims 1 to 12, wherein said tilt angle of said swash plate can be changed through a cam mechanism interposed between said main shaft and said swash plate, and a cam profile of said cam mechanism is set so that a momentary rotation center of said swash plate is given at a position at which a load due to a compression reactive force of at least one piston among a plurality of pistons present in a compression stroke operates as a couple moment acting in a direction for decreasing displacement relatively to said swash plate.

14. The variable displacement compressor according to claim 13, wherein said cam mechanism comprises a sliding engagement mechanism formed by a slot formed on one of an arm extending from main shaft side and an arm extending from swash plate side and a pin provided on the other, and said cam profile is set by forming a shape of said slot as an S-shape.

15. The variable displacement compressor according to any of claims 1 to 14, wherein respective parts are set so that a total balance of a couple moment generated in a tilt angle changing plane of said swash plate by at least rotational and reciprocal movement of said respective parts becomes one in a direction for decreasing tilt angle in every tilt angle of said swash plate.

16. The variable displacement compressor according to claim 15, wherein a spring for urging at least said swash plate in a direction for decreasing tilt angle is further provided, and a total balance of a couple moment generated in a tilt angle changing plane of said swash plate by said rotational and reciprocal movement including by an urging force of said spring is set so as to become one in a direction for decreasing tilt angle in every tilt angle of said swash plate.

FIG. 1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P s
P d
P m
: flow of suction gas
: flow of control gas
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FIG. 2

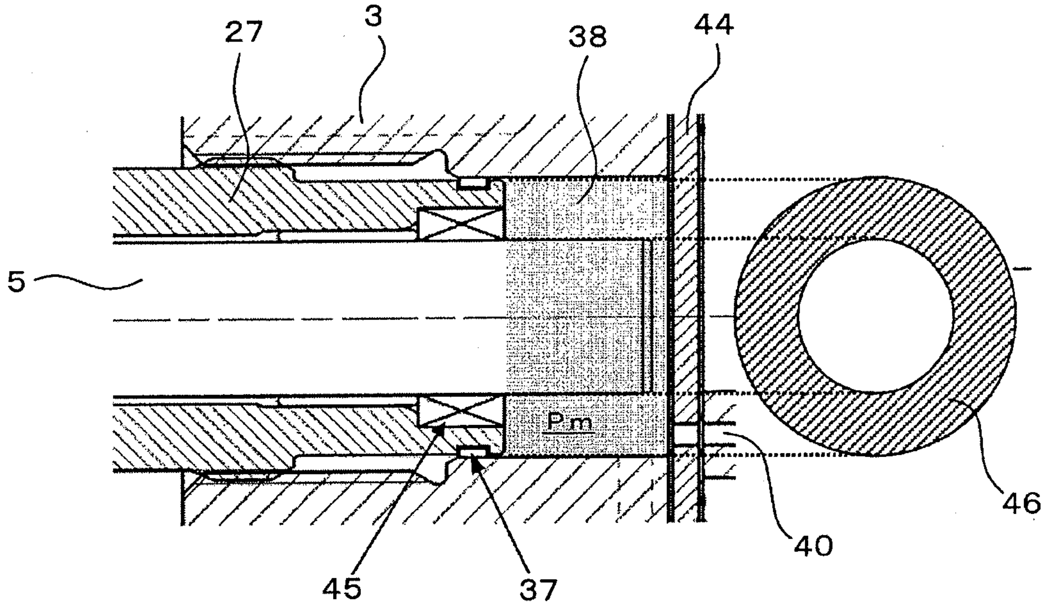

FIG. 3

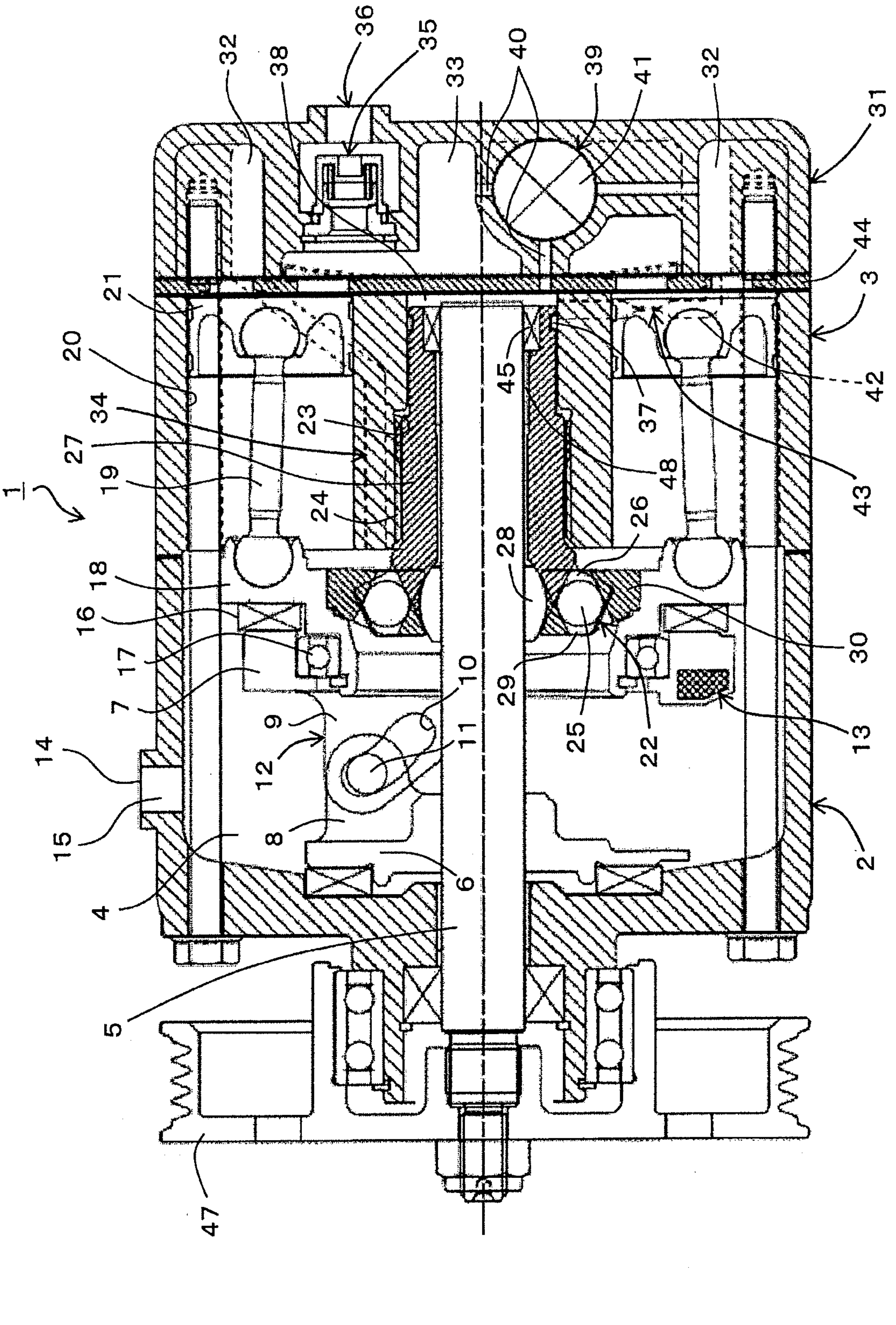
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FIG. 4

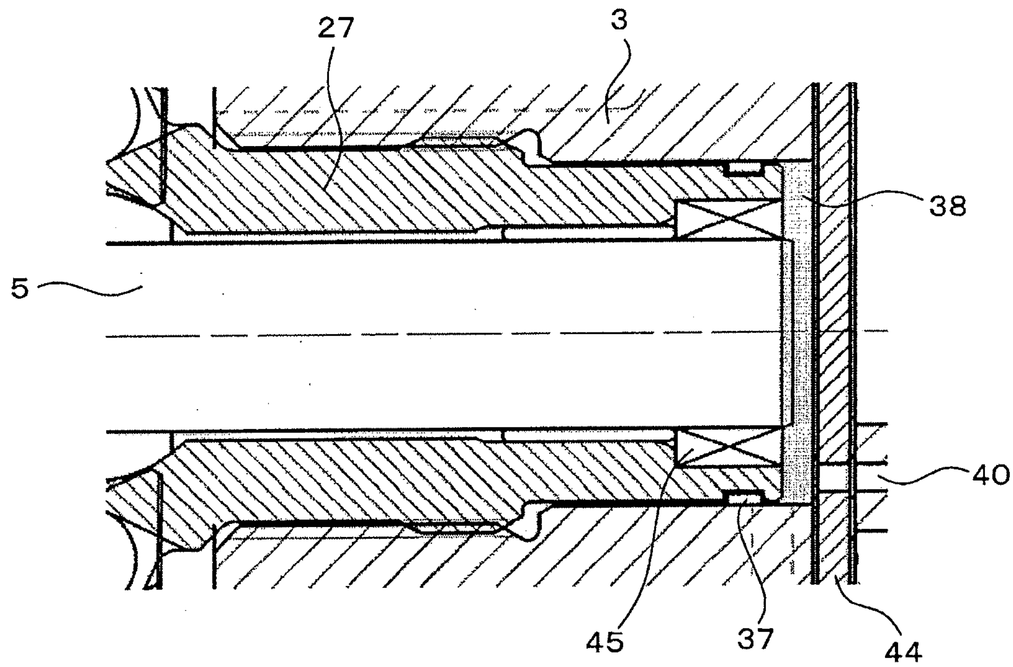
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FIG. 5

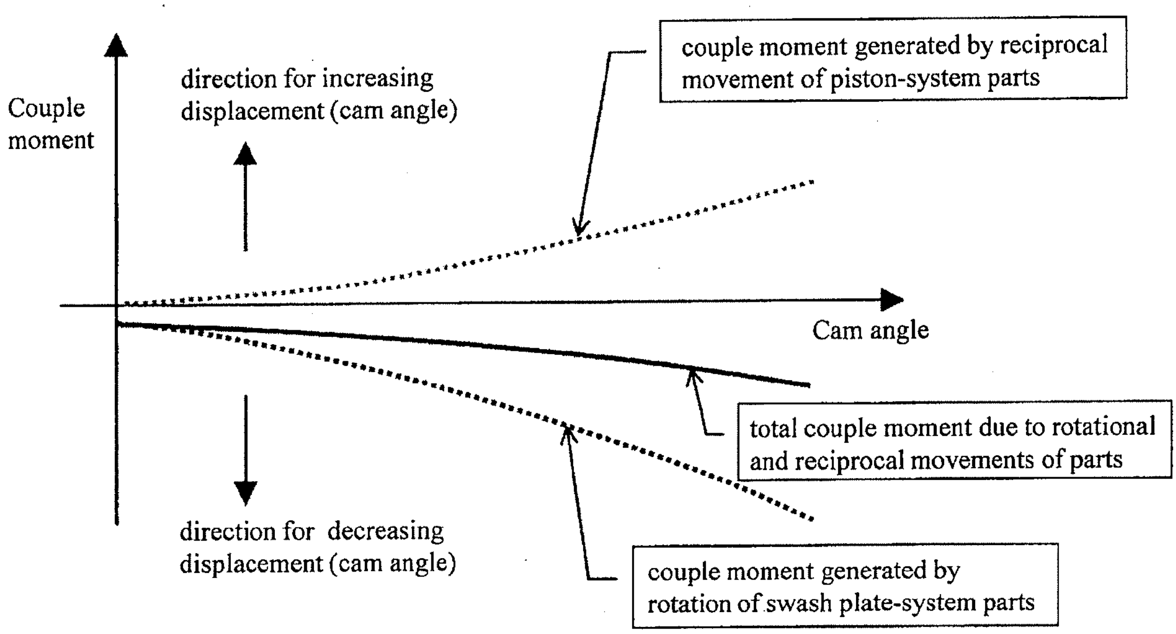
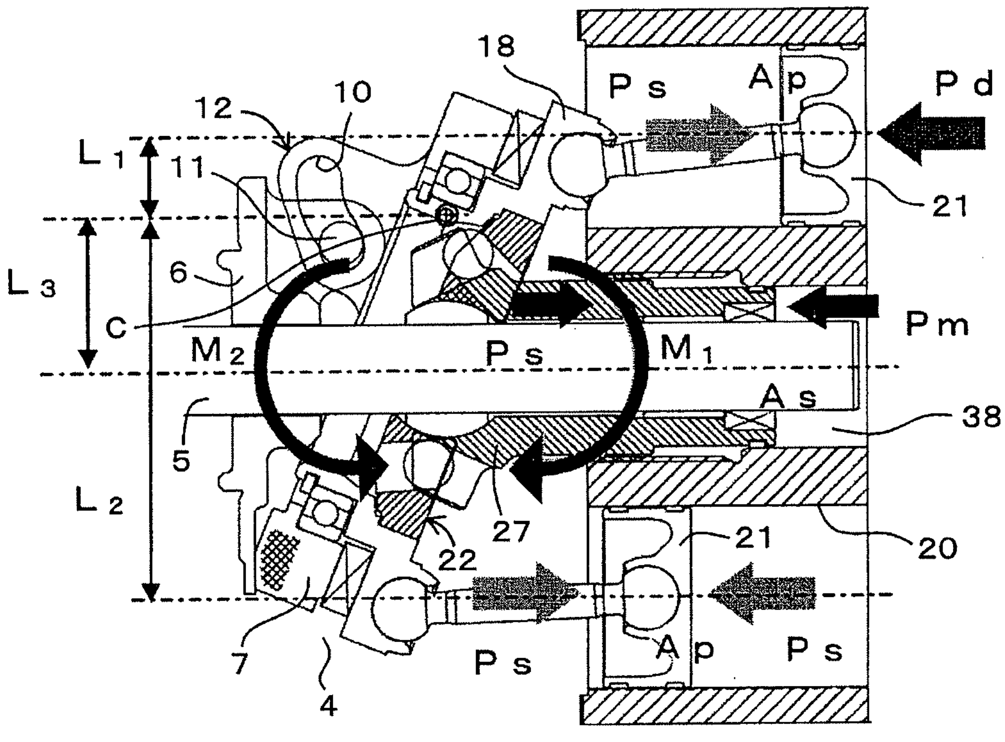

Couple moment
direction for increasing displacement (cam angle)
couple moment generated by reciprocal movement of piston-system parts
Cam angle
total couple moment due to rotational and reciprocal movements of parts
direction for decreasing displacement (cam angle)
couple moment generated by rotation of swash plate-system parts

FIG. 6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L3
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Pm
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21
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7
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Ps
Ap
Ps

FIG. 7

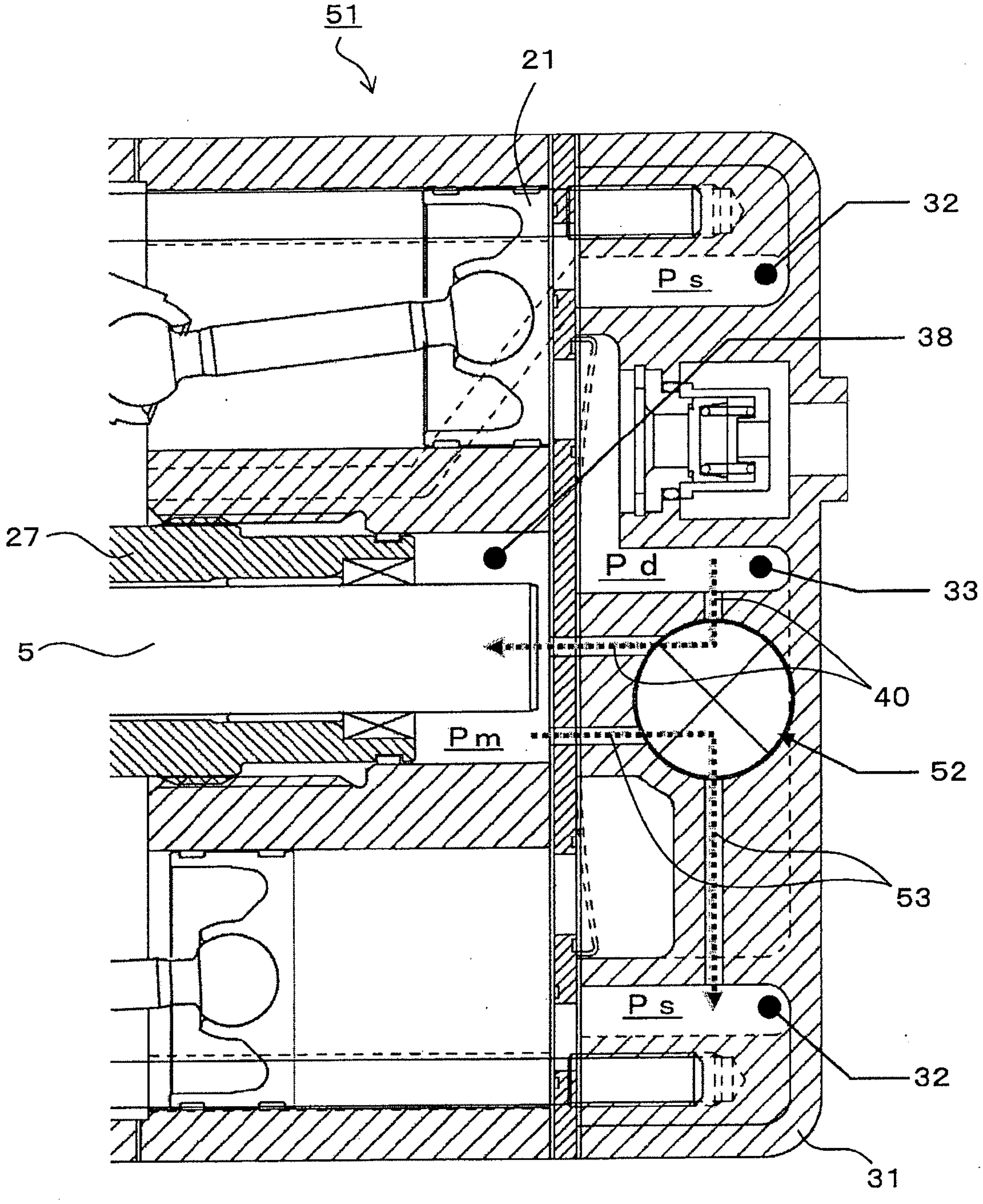

FIG. 8

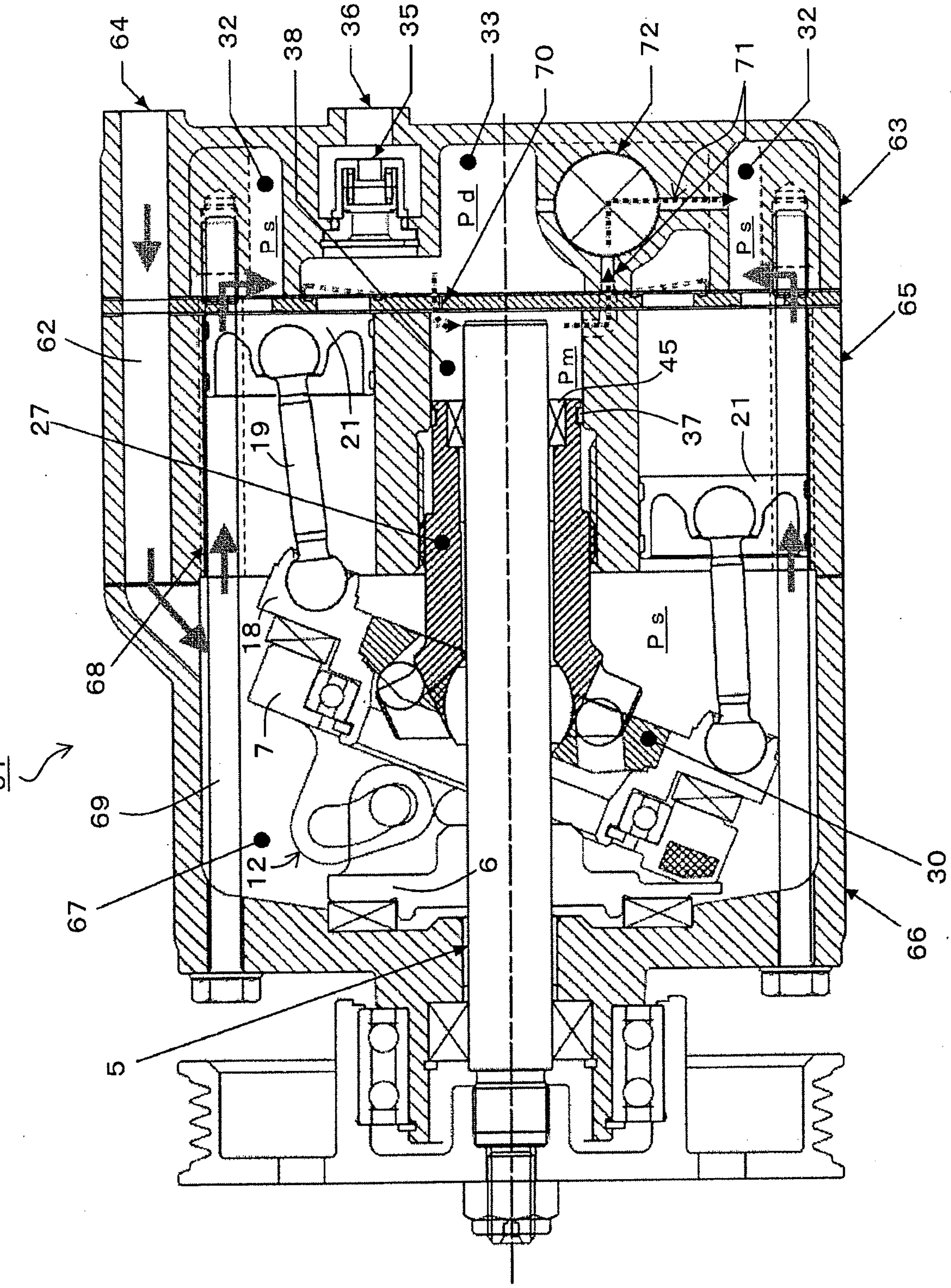
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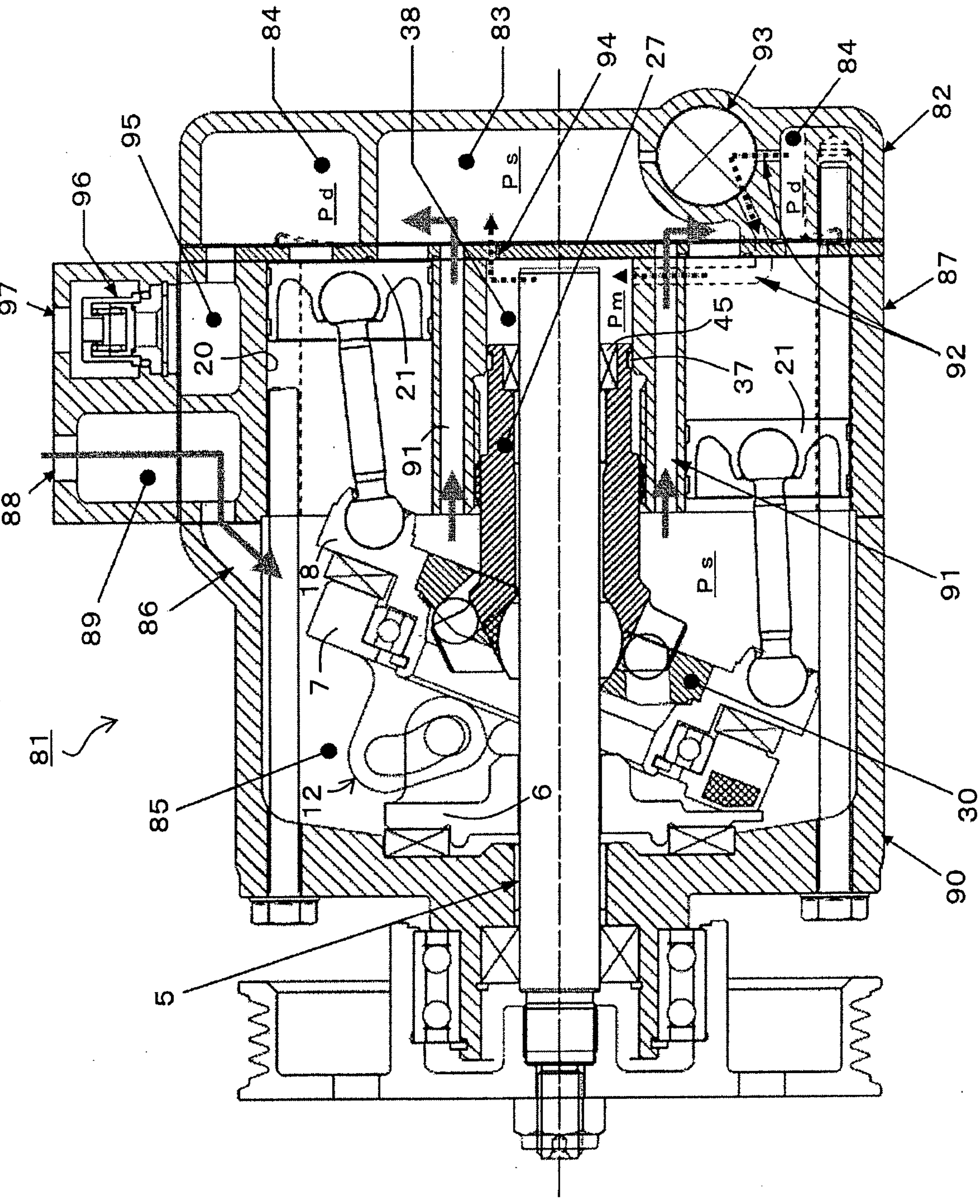
FIG.9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P s
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FIG.10

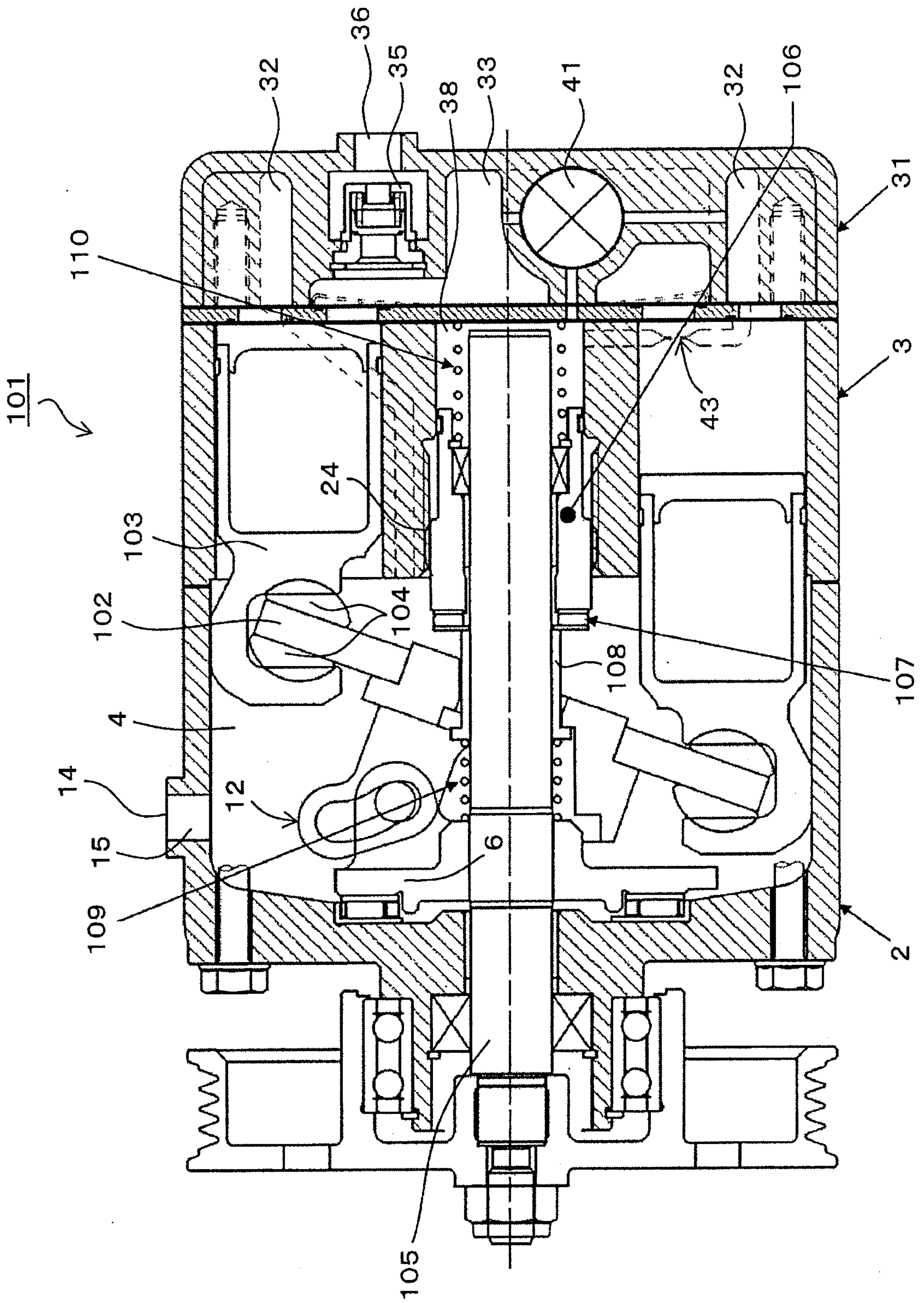
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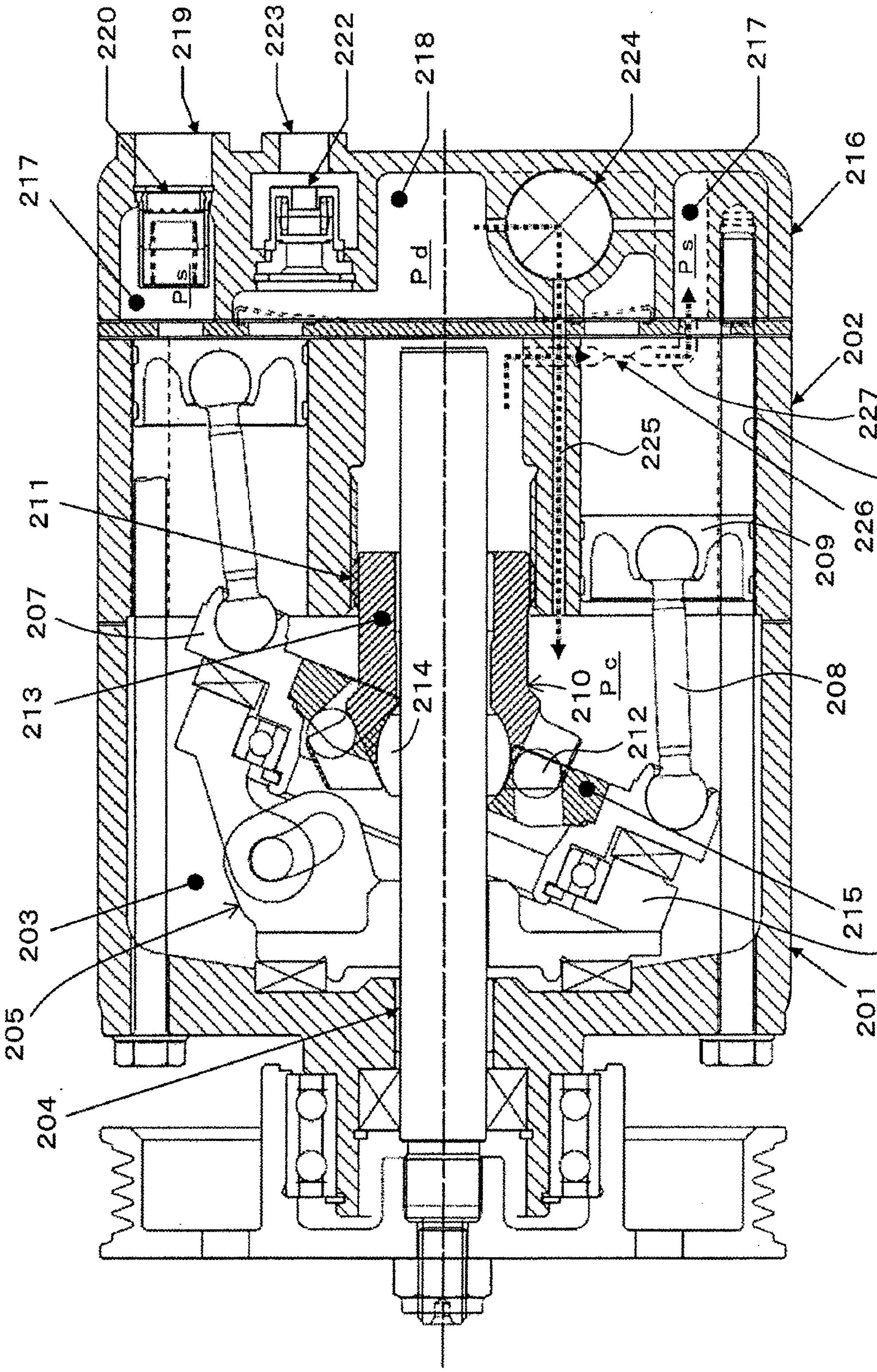
FIG.11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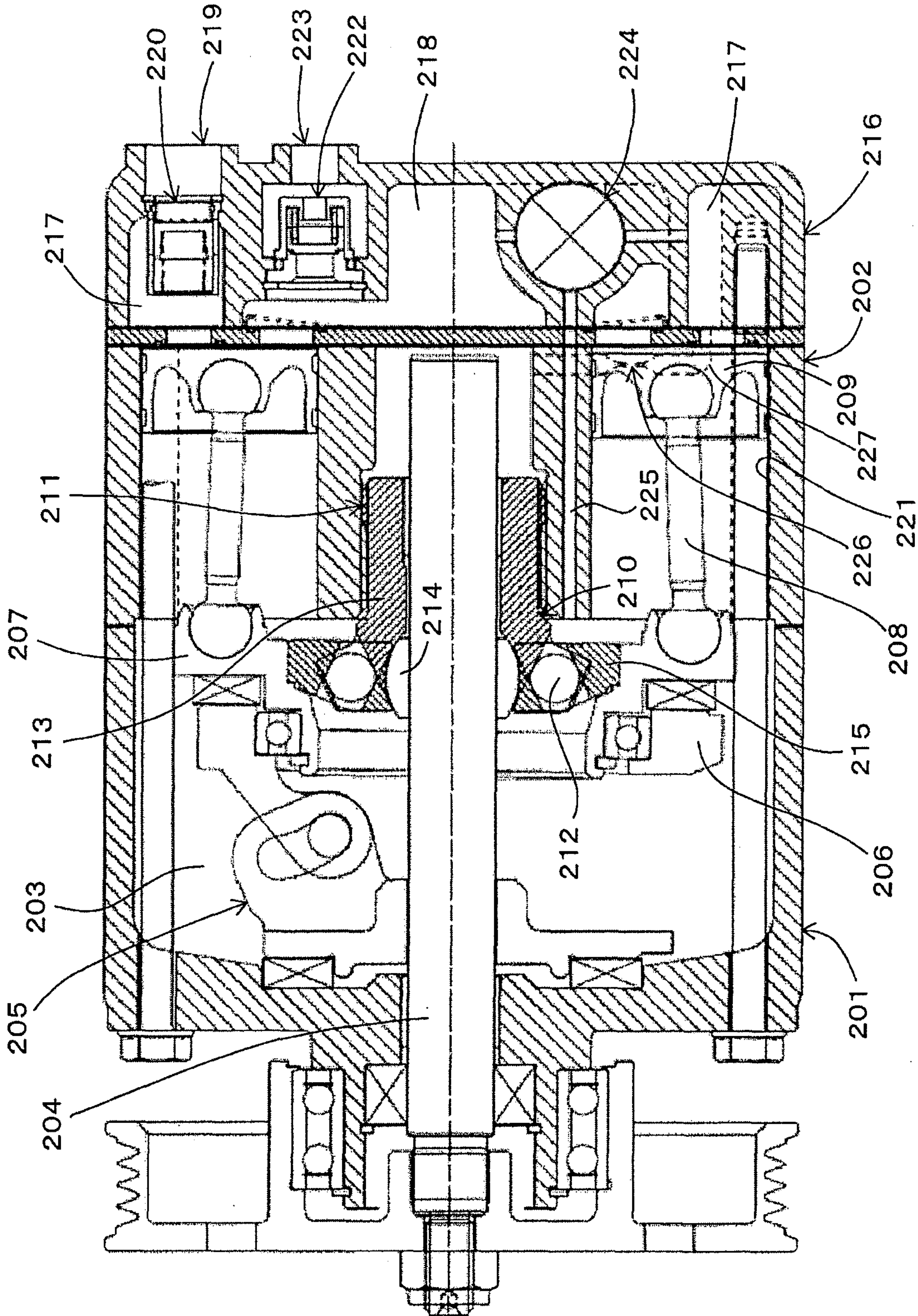
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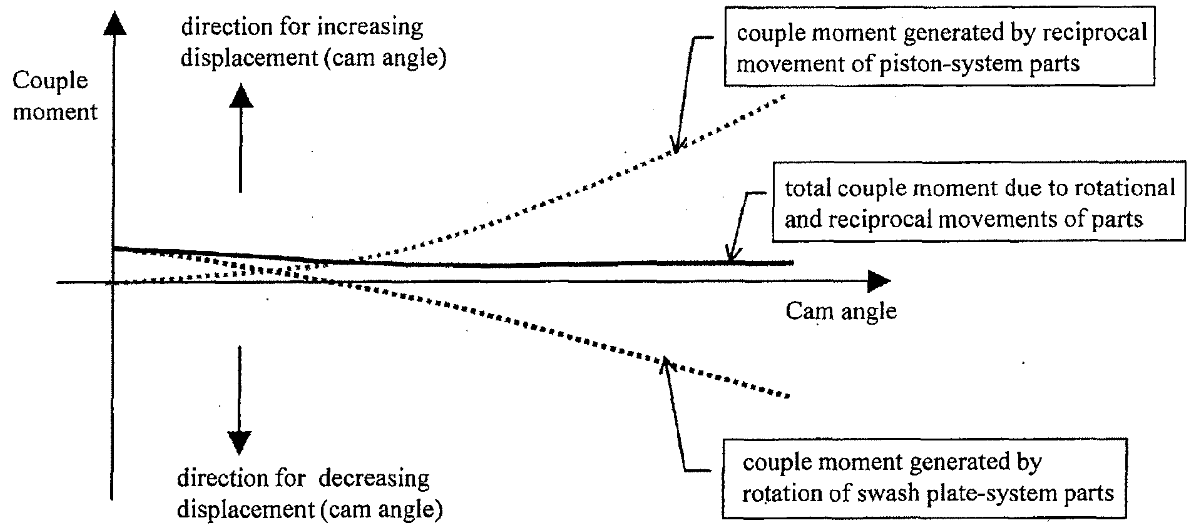
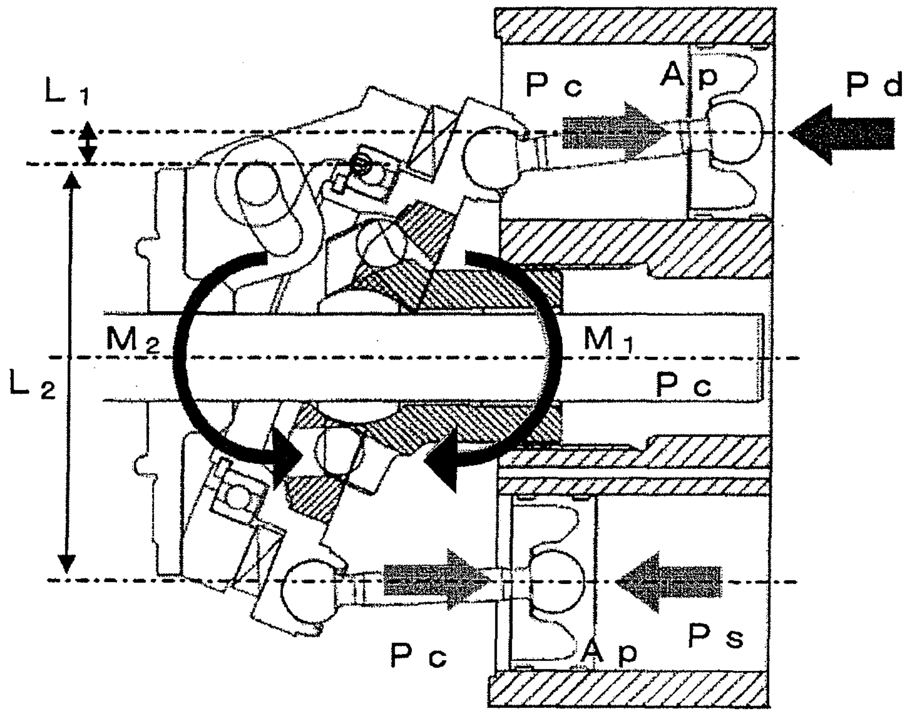
FIG.12

FIG. 13



Couple moment
direction for increasing displacement (cam angle)
couple moment generated by reciprocal movement of piston-system parts
total couple moment due to rotational and reciprocal movements of parts
Cam angle
couple moment generated by rotation of swash plate-system parts
direction for decreasing displacement (cam angle)

FIG. 14



L 1
P c
A p
P d
M 2
M 1
L 2
P c
P c
A p
P s

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/003724

A. CLASSIFICATION OF SUBJECT MATTER
F04B27/08(2006.01)i, *F04B27/14*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B27/08, F04B27/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 1-182581 A (Honda Motor Co., Ltd.), 20 July 1989 (20.07.1989), claims; page 4, upper right column, line 14 to lower right column, line 9; page 5, lower right column, line 15 to page 6, lower left column, line 1; fig. 1 & WO 1989/006752 A1	1-5,9 10-12 6-8,13-16
Y A	JP 2008-138637 A (Sanden Corp.), 19 June 2008 (19.06.2008), claim 1; fig. 1 & WO 2008/069001 A1	10-11 6-8,13-16
Y A	JP 2008-248857 A (Denso Corp.), 16 October 2008 (16.10.2008), paragraphs [0019], [0032] to [0037]; fig. 1, 7 & CN 101275546 A	10-12 6-8,13-16

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 September, 2010 (16.09.10)	28 September, 2010 (28.09.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/003724

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-507627 A (Zexel Valeo Compressor Europe GmbH), 25 February 2003 (25.02.2003), paragraphs [0017] to [0027]; fig. 1 to 2 & WO 2001/012989 A1	1-16
A	JP 9-273483 A (Toyoda Automatic Loom Works, Ltd.), 21 October 1997 (21.10.1997), entire text; all drawings & FR 2747159 A1	1-16
A	WO 2008/146806 A1 (Sanden Corp.), 04 December 2008 (04.12.2008), entire text; all drawings (Family: none)	13-16

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/003724

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheets.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/003724

Continuation of Box No.III of continuation of first sheet(2)

The invention specifying matter of the invention of claim 1, that is, the technical feature common among the inventions of claims 1-16 is publicly known and cannot be said to have any special technical feature, since it is disclosed in JP 1-182581 A (Honda Motor Co., Ltd.), 20 July 1989 (20.07.1989), claims, line 14, upper right column to line 9, lower right column, page 4, and line 15, lower right column, page 5 to line 1, lower left column, page 6, fig. 1.

Moreover, it is not admitted that there is other same or corresponding special technical feature among the inventions of claims 1-16.

Hence, the claims contain the following three inventions.

(Invention 1) Invention of claims 1-2, and invention of claims 5-16 having the following special technical features

"A variable capacity compressor comprising a cylinder head having a suction chamber and a discharge chamber formed therein, a cylinder block having a cylinder bore, in which a piston is reciprocatively inserted, a crank chamber formed of said cylinder block and a front housing, a swash plate arranged in said crank chamber and supported to rotate together with a main shaft and to have the inclination angle thereof made variable with respect to said main shaft, and a motion converting mechanism for converting the rotating motions of said swash plate into the reciprocating motions of said piston, wherein a suction passage for sucking the suction gas into the compressor is formed to open into said crank chamber, wherein said suction passage is formed in said front housing, wherein said cylinder block has a communication passage formed to connect said crank chamber and said suction chamber in a communicating manner, wherein an axially moving member movable in a direction along the axis of said main shaft is provided around said main shaft in a manner to correspond substantially one-to-one to the inclination angle of said swash plate, and wherein said axially moving member is so arranged that the pressure in said crank chamber may be applied to one end side thereof and that an intermediate pressure between the pressure in said discharge chamber and the pressure in said suction chamber may be applied to the other end side thereof, and further comprising an intermediate pressure control mechanism capable of controlling said intermediate pressure".

(continued to next extra sheet)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/003724

(Invention 2) Invention of claim 3, and invention of claims 5-16 having the following special technical features

"A variable capacity compressor comprising a cylinder head having a suction chamber and a discharge chamber formed therein, a cylinder block having a cylinder bore, in which a piston is reciprocatively inserted, a crank chamber formed of said cylinder block and a front housing, a swash plate arranged in said crank chamber and supported to rotate together with a main shaft and to have the inclination angle thereof made variable with respect to said main shaft, and a motion converting mechanism for converting the rotating motions of said swash plate into the reciprocating motions of said piston, wherein a suction passage for sucking the suction gas into the compressor is formed to open into said crank chamber, wherein said suction passage is formed to extend from said cylinder block to said front housing, wherein said cylinder block has a communication passage formed to connect said crank chamber and said suction chamber in a communicating manner, wherein an axially moving member movable in a direction along the axis of said main shaft is provided around said main shaft in a manner to correspond substantially one-to-one to the inclination angle of said swash plate, and wherein said axially moving member is so arranged that the pressure in said crank chamber may be applied to one end side thereof and that an intermediate pressure between the pressure in said discharge chamber and the pressure in said suction chamber may be applied to the other end side thereof, and further comprising an intermediate pressure control mechanism capable of controlling said intermediate pressure".

(Invention 3) Invention of claim 4, and invention of claims 5-16 having the following special technical features

"A variable capacity compressor comprising a cylinder head having a suction chamber and a discharge chamber formed therein, a cylinder block having a cylinder bore, in which a piston is reciprocatively inserted, a crank chamber formed of said cylinder block and a front housing, a swash plate arranged in said crank chamber and supported to rotate together with a main shaft and to have the inclination angle thereof made variable with respect to said main shaft, and a motion converting mechanism for converting the rotating motions of said swash plate into the reciprocating motions of said piston, wherein a suction passage for sucking the suction gas into the compressor is formed to open into said crank chamber, wherein said suction passage is formed to extend from said cylinder head through said cylinder block to said front housing, wherein said cylinder block has a communication passage formed to connect said crank chamber and said suction chamber in a communicating manner, wherein an axially moving member movable in a direction along the axis of said main shaft is provided around said main shaft in a manner to correspond substantially one-to-one to the inclination angle of said swash plate, and wherein said axially moving member is so arranged that the pressure in said crank chamber may be applied to one end side thereof and that an intermediate pressure between the pressure in said discharge chamber and the pressure in said suction chamber may be applied to the other end side thereof, and further comprising an intermediate pressure control mechanism capable of controlling said intermediate pressure".

(Of the invention of claim 1 and the inventions of claims 5-16, the inventions depending neither directly nor indirectly on any of claims 2-4 are classified into invention 1.)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008138637 A **[0010]**
- JP 8189464 A **[0010]**
- JP 9273483 A **[0010]**