(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 070 845 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
24.01.2001 Bulletin 2001/04

(21) Application number: **00902118.9**

(22) Date of filing: **07.02.2000**

(51) Int. Cl.[7]: **F04B 27/08**, F04B 27/14

(86) International application number:
PCT/JP00/00650

(87) International publication number:
WO 00/47896 (17.08.2000 Gazette 2000/33)

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **10.02.1999 JP 3289599**

(71) Applicant:
Kabushiki Kaisha Toyoda Jidoshokki Seisakusho
Aichi-ken 448-8671 (JP)

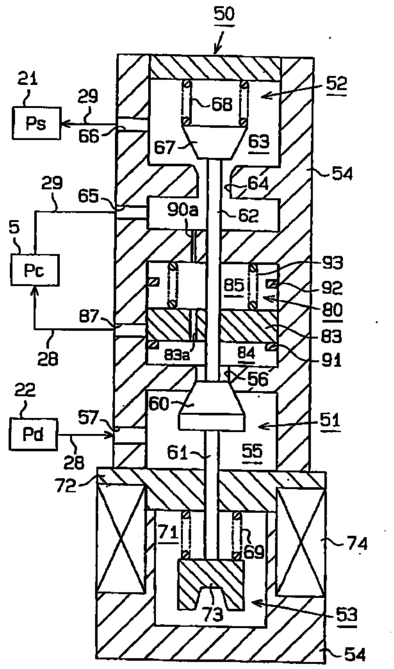
(72) Inventors:
- **OTA, Masaki,**
  Kabushiki Kaisha Toyoda
  Kariya-shi, Aichi 448-8671 (JP)
- **SUITOU, Ken,**
  Kabushiki Kaisha Toyoda
  Kariya-shi, Aichi 448-8671 (JP)
- **MATSUBARA, Ryo,**
  Kabushiki Kaisha Toyoda
  Kariya-shi, Aichi 448-8671 (JP)
- **ADANIYA, TakuKabushiki Kaisha Toyoda**
  Kariya-shi, Aichi 448-8671 (JP)

(74) Representative:
Leson, Thomas Johannes Alois, Dipl.-Ing. et al
Patentanwälte
Tiedtke-Bühling-Kinne & Partner,
Bavariaring 4
80336 München (DE)

(54) **CRANK PRESSURE CONTROL MECHANISM OF VARIABLE DISPLACEMENT COMPRESSOR**

(57) A variable displacement compressor has a discharge pressure zone, the pressure of which is a discharge pressure, and a supply passage for supplying gas from the discharge pressure zone to a crank chamber. An inlet valve mechanism opens or closes the supply passage to control the pressure in the crank chamber. An adjusting mechanism is located in the supply passage between the inlet valve mechanism and the crank chamber. The adjusting mechanism gradually varies the amount of gas supplied from the discharge pressure zone to the crank chamber through the supply passage. This results in a rapid shift to the minimum displacement and operates the compressor with optimum efficiency.

Fig.6



EP 1 070 845 A1

Description

Technical Field

[0001] The present invention relates to a crank pressure control mechanisms of a variable displacement compressors that change the inclination angle of a swash plate depending on the internal pressure of a crank chamber to change the displacement.

Background Art

[0002] Generally, in a swash plate type variable displacement compressor, the inclination angle of a swash plate changes depending on the internal pressure (crank pressure Pc) of a crank chamber. The displacement of the compressor is changed depending on the inclination angle of the swash plate. Inlet control is one conventional method for controlling the crank pressure Pc. With inlet control, the inflow of a coolant gas from a discharge chamber to the crank chamber is controlled by an inlet control valve. In the inlet control method, the inclination of the swash plate is reduced by increasing the crank pressure Pc to lower the displacement of the compressor. According to the inlet control method, when the displacement of a compressor is changed at once from maximum to minimum and is then maintained at the minimum displacement, the closed inlet control valve must be opened fully and then held fully open.

[0003] However, when the inlet control valve is maintained in the fully open state, the crank pressure Pc can become too high. In other words, the crank pressure Pc increases beyond a predetermined target value. An excessively high crank pressure Pc can cause the end faces of the pistons to strike a valve plate when the pistons reach their top dead center positions.

[0004] In order to prevent this, there is an existing design that limits the crank chamber pressure by placing a fixed restriction with a relatively great diameter in a bleed passage, which releases gas in the crank chamber to the suction chamber.

[0005] However, in order to maintain the discharge displacement of a compressor at the minimum displacement, coolant gas must be supplied continuously from the discharge chamber to the crank chamber in an amount that is more than that flowing from the crank chamber through the bleed passage. This produces a flow of coolant gas from the discharge chamber, through the crank chamber, into the suction chamber, which wastes compressed coolant gas and reduces the efficiency of the compressor.

[0006] When the discharge displacement of a compressor is changed from the maximum to the minimum (i.e., when the inclination of the swash plate is changed from the maximum angle to the minimum angle), the inclination angle of the swash plate must be changed at once. Accordingly, it is preferred that the inlet control valve be opened fully during the period when the crank pressure Pc increases from a low value corresponding to the maximum inclination angle position of the swash plate to a high value necessary for shifting the swash plate to the minimum inclination angle position.

Disclosure of the Invention

[0007] It is therefore an object of the present invention to provide a crank pressure control mechanism for a variable displacement compressor that can rapidly change the discharge displacement of the compressor to the minimum value and can operate the compressor with optimum efficiency.

[0008] To achieve the above object, this invention provides a variable displacement compressor for varying the displacement. The compressor includes a discharge pressure zone, the pressure of which is a discharge pressure. A supply passage supplies gas from the discharge pressure zone to the crank chamber. An inlet valve mechanism is located in the supply passage. The inlet valve mechanism opens and closes the supply passage to control the pressure in the crank chamber. An adjusting mechanism is located in the supply passage between the inlet valve mechanism and the crank chamber. The adjusting mechanism gradually varies the amount of gas that flows from the discharge pressure zone to the crank chamber through the supply passage when the inlet valve mechanism is open.

Brief Description of the Drawings

[0009]

Figure 1 is a cross-sectional view of a swash plate type variable displacement compressor according to a first embodiment of the present invention;

Figure 2 is a cross-sectional view showing a state where a charge passage of an electromagnetic valve in the compressor shown in Figure 1 is closed;

Figure 3 is a cross-sectional view showing a state where a bleed passage of the electromagnetic valve shown in Figure 2 is closed;

Figure 4 is a cross-sectional view of a part of the electromagnetic valve shown in Figure 2 when that part of the valve acts as a differential pressure regulating valve;

Figure 5(A) is a cross-sectional view showing a state where an outlet port of an adjusting mechanism in the compressor shown in Figure 1 is closed;

Figure 5(B) is a cross-sectional view showing a state where the outlet port in the adjusting mechanism shown in Figure 5(A) is opened;

Figure 6 is a cross-sectional view showing a state where an outlet port of an electromagnetic valve in a second embodiment is closed;

Figure 7 is a cross-sectional view showing a state where the outlet port of the electromagnetic valve shown in Figure 6 is opened;

Figure 8 is a cross-sectional view showing a part of an electromagnetic valve in a third embodiment; and

Figure 9 is a block diagram schematically showing a compressor according to a fourth embodiment.

Best Mode for Carrying Out the Invention

[0010] Figures 1-5(B) show a swash plate type variable displacement compressor having a clutch.

[0011] As shown in Figure 1, a cylinder block 1 is combined with a front housing 2 and a rear housing 4. A valve plate 3 is located between the cylinder block 1 and the rear housing 4. The cylinder block 1, the front housing 2, the valve plate 3 and the rear housing 4 are joined with a plurality of through bolts (not shown) to constitute a compressor housing.

[0012] A crank chamber 5 is defined between the cylinder block 1 and the front housing 2. A drive shaft 6 is supported by the cylinder block 1 and the front housing 2 rotatable via a plurality of radial bearings.

[0013] A bore for containing a helical spring 7 and a rear thrust bearing 8 is formed substantially at the center of the cylinder block 1. In the crank chamber 5, a rotating support 11 is fixed on the drive shaft 6 to rotate integrally with the drive shaft 6. A front thrust bearing 9 is located between the rotating support 11 and an inner surface of the front housing 2. The drive shaft 6 is supported in the axial direction by the thrust bearings 8 and 9, which are urged forward by the spring 7.

[0014] The drive shaft 6 is connected via an electromagnetic clutch 40 to an engine E, which is an external drive source. The electromagnetic clutch 40 includes a pulley 42, an annular solenoid coil 43 and an armature 45. The pulley 42 is supported by a bearing 41 at the front end of the front housing 2. The armature 45 is connected to the drive shaft 6 by a leaf spring 44.

[0015] When electric current is supplied to the coil 43, an electromagnetic attraction is generated between the armature 45 and the pulley 42, which causes the armature 45 to engage the pulley 42 as shown in Figure 1. Then, the power of the engine E is transmitted to the drive shaft 6 via a transmission belt 46, the pulley 42, the armature 45 and the leaf spring 44. When the supply of electric current to the coil 43 is interrupted, the armature 45 is separated from the pulley 42 by the force of the leaf spring 44 to interrupt the power transmission. Thus, driving power of the engine can be transmitted to the drive shaft 6 selectively by controlling supply of electric current to the coil 43.

[0016] A swash plate 12, or drive plate, is housed in the crank chamber 5. The drive shaft 6 passes through a center hole formed in the swash plate 12. The swash plate 12 is connected via a hinge mechanism 13 to the rotating support 11 and the drive shaft 6. The hinge mechanism 13 consists essentially of supporting arms 14, which have guide holes, provided on the rotating support 11 and guide pins 15, which have spherical heads, provided on the front side of the swash plate 12. The hinge mechanism 13 causes the swash plate 12 to rotate integrally with the drive shaft 6 and permits movement of the swash plate 12 in the axial direction of the drive shaft 6 and inclination of the swash plate 12 with respect to the axis of the drive shaft 6.

[0017] A helical spring 16 is fitted around the drive shaft 6 between the rotating support 11 and the swash plate 12. The spring 16 urges the swash plate 12 in a direction such that the inclination angle of the swash plate 12 decreases. A snap ring 17 is fixed on the drive shaft 6 between the swash plate 12 and the cylinder block 1. The snap ring 17 limits rearward movement of the swash plate 12, which limits the minimum inclination angle of the swash plate 12 to, for example, three to five degrees. The maximum inclination angle of the swash plate 12 is determined by the abutment of a counterweight 12a formed on the swash plate 12 against a restricting section 11a of the rotating support 11.

[0018] A plurality of cylinder bores 1a (only one bore 1a is shown) are defined in the cylinder block 1. The cylinder bores 1a are arranged at predetermined angular intervals along a circle drawn about the axis of the drive shaft 6.

[0019] A single-headed piston 18 is housed in each cylinder bore 1a. Each piston 18 is connected to the swash plate 12 via a pair of shoes 19.

[0020] A suction chamber 21 and a discharge chamber 22 are defined in the rear housing 4. The valve plate 3 contains a suction port 23, a suction valve 24, a discharge port 25 and a discharge valve 26 for each cylinder bore 1a. The suction chamber 21 is connected to each cylinder bore 1a via the suction port 23. Each cylinder bore 1a is connected with the discharge chamber 22 via the discharge port 25.

[0021] The drive shaft 6 is rotated when the engine E is running, and the swash plate 12 rotates with the rotation of the shaft 6. The rotational movement of the swash plate 12 is converted by the shoes 19 into reciprocating movement of the pistons 18. This reciprocating movement compresses a coolant gas drawn from the suction chamber 21, through the valve plate 3, into the cylinder bore 1a. The compressed coolant gas is discharged from the cylinder bore 1a into the discharge chamber 22.

[0022] The inclination angle of the swash plate 12 is determined by various moments acting on the swash plate 12, which include a rotational moment based on the centrifugal force of the rotating swash plate 12, a moment based on the urging force of the spring 16 and a moment based on gas pressure. The moment of the rotational movement acts on the swash plate 12 to increase the inclination angle. The gas pressure moment is based on the reaction force of compression acting on the pistons 18 in the compression strokes, the internal pressures of the cylinder bores 1a acting upon the pistons 18 in the suction strokes, and the internal pressure (crank pressure Pc) of the crank chamber 5. The moment based on the gas pressure acts on the swash plate 12 to decrease the inclination angle.

[0023] In this embodiment, the sum of the moment based on the gas pressure and the moment based on the urging force of the spring 16 becomes greater than the moment of the rotational movement when the crank pressure Pc is maintained at a relatively high level. Accordingly, the swash plate 12 shifts to the minimum inclination angle position. The sum of the moment based on the gas pressure and the moment based on the spring force is balanced with the moment of the rotational movement by adjusting the crank pressure Pc. Thus, the inclination of the swash plate 12 can be set at a desired angle between the minimum inclination angle position and the maximum inclination angle position of the swash plate 12. The stroke of each piston 18, or the discharge displacement of the compressor, is also adjusted depending on the inclination angle of the swash plate 12.

[0024] As shown in Figures 1 to 5, the control mechanism for controlling the crank pressure Pc includes an inlet side/outlet side interlocking type electromagnetic valve 50, an adjusting mechanism 80 for adjusting inflow of gas, a supply passage 28, and a bleed passage 29. Both passages 28, 29 are defined in the compressor housing. The supply passage 28 connects the discharge chamber 22 to the crank chamber 5. An inlet valve mechanism 51 and the adjusting mechanism 80 of the electromagnetic valve 50 are located in the supply passage 28. The bleed passage 29 connects the crank chamber 5 to the suction chamber 21. An outlet valve mechanism 52 of the electromagnetic valve 50 is located in the bleed passage 29.

[0025] As shown in Figure 1, the discharge chamber 22 and the suction chamber 21 are connected to each other via an external coolant circuit 30. The external coolant circuit 30 constitutes, together with the compressor, a cooling circuit of a vehicular air conditioner. The external coolant circuit 30 is provided with a condenser 31, a thermostatic expansion valve 32 and an evaporator 33. The opening size of the expansion valve 32 is feedback-controlled based on the temperature detected by a temperature detecting cylinder located at the outlet of the evaporator 33 and the evaporating pressure. The outlet temperature of the evaporator 33 reflects the thermal load applied to a refrigerator circuit. The expansion valve 32 supplies an appropriate amount of coolant to the evaporator 33 depending on the thermal load applied to the refrigerator circuit. Thus, the flow rate of the coolant gas in the external coolant circuit 30 can be adjusted.

[0026] As shown in Figure 2, a temperature sensor 34 is located adjacent to the evaporator 33. The temperature sensor 34 detects the temperature of the evaporator 33 and outputs a signal indicating the detection result to a controller C. The controller C is a computer, which controls heating and cooling of the vehicle air conditioner. The temperature sensor 34, a cabin temperature sensor 35 for detecting the temperature in the passenger compartment, a cabin temperature setter 36 for setting the temperature in the passenger compartment, an actuating switch 37 and an electronic control unit (ECU) are connected to the input side of the controller C. A drive circuit 38 for controlling the supply of electric current to the solenoid coil 43 of the electromagnetic clutch 40 and another drive circuit 39 for controlling the supply of electric current to a coil 74 of the electromagnetic valve 50 are connected to the output side of the controller C.

[0027] The controller C controls the electromagnetic clutch 40 and the electromagnetic valve 50 based on various information including the temperature of the evaporator 33 detected by the temperature sensor 34, the temperature detected by the cabin temperature sensor 35, the temperature set by the cabin temperature setter 36, the ON/OFF state of the switch 37 and information from the ECU such as whether the engine E is running and engine revolution speed.

[0028] The electromagnetic valve 50 is provided with an inlet valve mechanism 51 for opening and closing the supply passage 28, an outlet valve mechanism 52 for opening and closing the bleed passage 29, and a solenoid 53 for driving the valve mechanisms 51 and 52. The valve mechanisms 51 and 52 and the solenoid 53 are incorporated into a valve housing 54 of the electromagnetic valve 50.

[0029] The inlet valve mechanism 51 is provided with an inlet valve chamber 55 defined in the valve housing 54 and a valve opening 56 communicating with the valve chamber 55. The inlet valve chamber 55 communicates with the discharge chamber 22 via a first port 57 and the supply passage 28. The inlet valve chamber 55 is exposed to the pressure (discharge pressure Pd) of the discharge chamber 22. The valve opening 56 communicates with the adjusting mechanism 80 and the crank chamber 5 via a second port 58 and the supply passage 28. The first port 57, the inlet valve chamber 55, the valve opening 56 and the second port 58 form part of the supply passage 28.

[0030] An inlet valve body 60 is located in the inlet valve chamber 55 and is movable in the axial direction of the electromagnetic valve 50. The valve element 60 moves to open and close the valve opening 56. A first rod 61 and a second rod 62 extend in the axial direction of the electromagnetic valve 50 from the lower end and the upper end of the valve element 60, respectively. The rods 61 and 62 pass through respective partitions in the valve housing 54. The valve element 60 and the first and second rods 61 and 62 can move between an upper limit position (see Figure 2) where the valve element 60 closes the valve opening 56 and a lower limit position (see Figure 3) where the valve element 60 fully opens the valve opening 56.

[0031] The outlet valve mechanism 52 is provided with an outlet valve chamber 63 and a valve opening 64, which communicates with the chamber 63. Both the chamber 63 and the opening 64 are defined in the valve housing 54. The valve opening 64 communicates with the crank chamber 5 via a third port 65 and the bleed passage 29. The outlet valve chamber 63 communicates with the suction chamber 21 via a fourth port 66 and the bleed passage 29. The pressure (suction pressure Ps) of the suction chamber 21 is applied to the outlet valve chamber 63. The third port 65, the valve opening 64, the outlet valve chamber 63 and the fourth port 66 form part of the bleed passage 29.

[0032] An outlet valve body 67 is located in the outlet valve chamber 63 and is movable in the axial direction of the electromagnetic valve 50. The valve element 67 moves in the outlet valve chamber 63 to open and close the valve opening 64. More specifically, the valve element 67 can move between an upper limit position (see Figure 2), in which the valve element 67 opens the valve opening 64, and the position illustrated in Figure 3, in which the valve element 67 closes the valve opening 64.

[0033] A first spring 68 is located between the outlet valve body 67 and a wall of the outlet valve chamber 63. The first spring 68 urges the outlet valve body 67 in the direction to close the valve opening 64. The distal end of the second rod 62 abuts against the lower surface of the outlet valve body 67. As shown in Figure 2, when the inlet valve body 60 is located at the upper limit position, the second rod 62 separates the outlet valve body 67 from the seat of the valve opening 64 against the downward urging force of the first spring 68. Thus, the valve opening 64 is opened. As shown in Figure 3, when the inlet valve body 60 is located at the lower limit position, the second rod 62 does not urge the outlet valve body 67 upward, and the valve element 67 is urged downward against the seat of the valve opening 64 by the first spring 68 to close the valve opening 64.

[0034] An electromagnetic actuator, or the solenoid 53 is provided with a plunger chamber 71 defined in the valve housing 54. A fixed iron core 72 is located between the plunger chamber 71 and the inlet valve chamber 55. The end of the first rod 61 is located in the plunger chamber 71. A movable iron core 73, which serves as a plunger, and a second spring 69 are also located in the plunger chamber 71. The movable iron core 73 is fixed at the distal end of the first rod 61. The second spring 69 is located between the fixed iron core 72 and the movable iron core 73. The second spring 69 urges the movable iron core 73, the inlet valve body 60 and the rods 61 and 62 as an integral body toward the bottom of the electromagnetic valve 50.

[0035] A coil 74 is wound around the valve housing 54 to surround the iron cores 72 and 73. A predetermined electric current is supplied to the coil 74 from the drive circuit 39 based on a command from the controller C. When electric current is supplied to the coil 74, electromagnetic attraction is generated between the iron cores 72 and 73.

[0036] The force of the electromagnetic attraction is transmitted to the valve bodies 60 and 67 via the first and second rods 61 and 62. Thus, the valve bodies 60 and 67 are moved to the positions shown in Figure 2 against the urging forces of the springs 68 and 69.

[0037] As described above, the inlet valve mechanism 51, outlet valve mechanism 52 and the solenoid 53 are linked with one another. The valve bodies 60 and 67 of the valve mechanisms 51 and 52 move depending on the presence or absence of the supply of electric current to the coil 74. That is, when electric current is supplied to the coil 74, the inlet valve mechanism 51 is closed and the outlet valve mechanism 52 is opened, as shown in Figure 2. When the supply of electric current to the coil 74 is interrupted, the inlet valve mechanism 51 is opened and the outlet valve mechanism 52 is closed, as shown in Figure 3. That is, the electromagnetic valve 50 opens either the inlet valve mechanism 51 or the outlet valve mechanism 52 selectively depending on a command from an external source.

[0038] When the outlet valve body 67 closes the valve opening 64, the crank pressure Pc can sometimes become too high. As a result, the differential pressure (Pc - Ps) acting on the valve element 67 applies a force that becomes greater than the urging force of the first spring 68. If this occurs, as shown in Figure 4, the valve element 67 shifts upward against the urging force of the first spring 68 to allow gas to flow into the suction chamber 21 from the crank chamber 5 through the valve opening 64 and the outlet valve chamber 63. Since the valve element 67 is not connected to the second rod 62, the outlet valve mechanism 52 functions also as a differential pressure regulating valve for limiting the crank pressure Pc.

[0039] As shown in Figures 2 and 3, the adjusting mechanism 80 is located in a downstream part of the supply passage 28, that is, between the second port 58 and the crank chamber 5. As shown in Figures 5(A) and 5(B), the adjusting mechanism 80 is provided with a spool valve element 83 accommodated in a storage chamber 82 defined in its housing 81. The spool valve element 83 is a movable body that can reciprocate between a first stopper 91 and a second stopper 92. The first and second stoppers 91,92 are provided on the inner walls of the storage chamber 82. More specifically, the spool valve element 83 can move between an advanced position (see Figure 5(A)) where the valve element 83 contacts the first stopper 91 and a retracted position (see Figure 5(B)) where the valve element 83 contacts the second stopper 92. The storage chamber 82 is divided by the valve element 83 into an inlet chamber 84 and a pressure control chamber 85.

[0040] The inlet chamber 84 communicates via an inlet port 86 with the second port 58 of the inlet valve mechanism 51. The inlet chamber 84 also communicates via an outlet port 87 and a first outlet passage 88 with the crank chamber 5. The outlet port 87 and the first outlet passage 88 form a first passage. The inlet chamber 84 and the pressure control chamber 85 communicate with each other via a first restriction 83a formed in the spool valve element 83. Further, the pressure control chamber 85 communicates via the port 89 and an second outlet passage 90 having a second restriction 90a with the crank chamber 5. The size, or diameter, of the second restriction 90a is smaller than that of the first restriction 83a. Accordingly, the amount of gas passing through the second restriction 90a is less than that passing through the first restriction 83a. The first restriction 83a, the pressure control chamber 85, the port 89 and the second outlet passage 90 form a second passage.

[0041] The pressure control chamber 85 contains a spring 93 that urges the spool valve element 83 toward the advanced position. When the internal pressure of the inlet chamber 84 is substantially equal to that of the pressure control chamber 85, the spring 93 urges the spool valve element 83 to the advanced position, and the valve element 83 closes an outlet port 87, as shown in Figure 5(A).

[0042] Next, operation of a swash plate type variable displacement compressor having the electromagnetic valve 50 and the adjusting mechanism 80 according to this embodiment will be described.

[0043] When the switch 37 is turned off, the electromagnetic clutch 40 interrupts transmission of power from the engine E to the compressor, and the compressor is not operated. At this time, no electric current is supplied to the coil 74 of the electromagnetic valve 50. Accordingly, as shown in Figure 3, the inlet valve mechanism 51 is opened and the outlet valve mechanism 52 is closed. If the inoperative state of the compressor continues for a relatively long time, the internal pressures of the chambers 5, 21 and 22 in the compressor are equalized, and the inclination of the swash plate 12 is maintained at the minimum angle by the urging force of the spring 16. When the switch 37 is turned on, the controller C outputs a command to the drive circuit 38 to supply electric current to the solenoid coil 43 of the electromagnetic clutch 40. Thus, the engine E is engaged with the compressor to operate the compressor.

[0044] When there is a great thermal load, the pressure around the outlet of the evaporator 33 (i.e., suction pressure Ps) is high, and the difference between the temperature detected by the cabin temperature sensor 35 and the temperature set by the cabin temperature setter 36 is also great. The controller C outputs a command to the drive circuit 39 to supply electric current to the coil 74 to increase the discharge capacity of the compressor. This generates electromagnetic attraction between the fixed iron core 72 and the movable iron core 73, which closes the inlet valve mechanism 51 and opens the outlet valve mechanism 52, as shown in Figure 2. Thus, the supply of gas from the discharge chamber 22 to the crank chamber 5 is interrupted, and the crank chamber 5 and the suction chamber 21 communicate with each other. Accordingly, the crank pressure Pc drops to about the suction pressure Ps, which reduces the moment based on gas pressure acting upon the swash plate 12. Consequently, the inclination of the swash plate 12 increases to the maximum inclination angle, which increases the displacement of the compressor to the maximum.

[0045] When the inlet valve mechanism 51 is closed, the crank pressure Pc is applied through the restrictions 90a and 83a of the adjusting mechanism 80 to the pressure control chamber 85 and the inlet chamber 84, so that the internal pressures of the crank chamber 5, the pressure control chamber 85 and the inlet chamber 84 are approximately the same. Accordingly, the spool valve element 83 moves to the advanced position and closes the outlet port 87.

[0046] When the increase in the discharge displacement of the compressor reduces the thermal load (or when the pressure Ps around the outlet of the evaporator 33 is lowered), the difference between the temperature detected by the cabin temperature sensor 35 and the temperature set by the cabin temperature setter 36 becomes small. At this time, the controller C outputs a command to the drive circuit 39 to interrupt the supply of electric current to the coil 74 to lower the discharge performance of the compressor. Thus, as shown in Figure 3, the inlet valve mechanism 51 is opened and outlet valve mechanism 52 is closed.

[0047] Immediately after opening the inlet valve mechanism 51, high pressure gas, the pressure of which is about the same as the discharge pressure Pd, is introduced into the inlet chamber 84 of the adjusting mechanism 80 through the port 58. Immediately before the introduction of the gas, the outlet port 87 is closed by the spool valve element 83 (see Figure 5(A)). The passage connecting the inlet chamber 84 and the pressure control chamber 85 includes the first restriction 83a. Accordingly, a differential pressure (Pd-Pc) is momentarily generated between the inlet chamber 84 and the pressure control chamber 85 immediately after introduction of the gas into the inlet chamber 84. This differential pressure drives the spool valve element 83 from the advanced position shown in Figure 5(A) to the retracted position shown in Figure 5(B) against the urging force of the spring 93, and thus the outlet port 87 is opened. As a result, the inlet chamber 84 communicates with the crank chamber 5 via the outlet port 87 and the first outlet passage 88, and gas is introduced directly from the discharge chamber 22 to the crank chamber 5.

[0048] After a predetermined time elapses from when the spool valve element 83 reaches the retracted position, the internal pressure of the inlet chamber 84 and that of the pressure control chamber 85 become equal to the discharge pressure Pd due to the flow of gas front the inlet chamber 84 through the first restriction 83a into the pressure control chamber 85. This is due to the fact that the size of the second restriction 90a on the outlet side of the pressure control chamber 85 is smaller than that of the first restriction 83a, and the flow of gas from the inlet chamber 84 to the pressure control chamber 85 is greater than that from the pressure control chamber 85 to the second outlet passage 90.

[0049] Due to the flow of gas from the inlet chamber 84 through the first restriction 83a into the pressure control chamber 85, the differential pressure between the chamber 84 and the chamber 85 becomes smaller. With the reduction of the differential pressure, the spring 93 urges the spool valve element 83 to move from the retracted position to the advanced position to close the outlet port 87. As described above, the outlet port 87 is opened only the while the spool valve element 83 moves from the advanced position to the retracted position and back to the advanced position. In other words, the adjusting mechanism 80 increases the amount of gas supplied from the discharge chamber 22 to the crank chamber 5 only while the spool valve element 83 moves back and forth a time. Here, the period during which the spool valve element 83 moves from the advanced position to the retracted position and back to the advanced position, or the period during which the outlet port 87 is opened, is determined mainly by the volume of the pressure control chamber 85 and the difference in the flow rate of gas passing through the two restrictions 83a and 90a.

[0050] When the electromagnetic valve 50 is in the position shown in Figure 3, the flow of gas from the crank chamber 5 to the suction chamber 21 is interrupted, while a minimum necessary amount of high-pressure gas rapidly flows into the crank chamber 5 through the inlet valve mechanism 51 and the adjusting mechanism 80, so that the crank pressure Pc rapidly increases to about the discharge pressure Pd. Accordingly, the moment based on the gas pressure is maximized, and the swash plate 12 is minimally inclined to minimize the discharge displacement of the compressor.

[0051] As long as the outlet valve mechanism 52 remains closed, the swash plate 12 maintains the minimum inclination angle. After the spool valve element 83 of the adjusting mechanism 80 closes the outlet port 87, gas having a pressure that is approximately equal to the discharge pressure Pd is supplied little by little from the pressure control chamber 85, which is exposed to the discharge pressure Pd, to the crank chamber 5 through the second restriction 90a. This gas makes up for the inevitable loss in the crank pressure Pc and is merely to maintain the crank pressure Pc in the current high-pressure state. If the crank pressure Pc is too high, the outlet valve mechanism 52 functions as a differential pressure regulating valve as described above with reference to Figure 4, to temporarily release gas from the crank chamber 5 to limit the crank pressure Pc.

[0052] When the thermal load increases again, the controller C resumes the supply of electric current to the coil 74. Thus, the inlet valve mechanism 51 and the outlet valve mechanism 52 are closed and opened respectively to increase the inclination angle or the swash plate 12. At this time, gas escapes from the inlet chamber 84 and the pressure control chamber 85 in the adjusting mechanism 80 only through the restrictions 83a and 90a into the crank chamber 5. Accordingly, the internal pressures of these chambers 84 and 85 fall gradually from the discharge pressure Pd toward the crank pressure Pc. Since the size of the first restriction 83a is greater than that of the second restriction 90a, there is no differential pressure between the chamber 84 and the chamber 85 when the chambers 84 and 85 are depressurized, and the spool valve element 83 is maintained at the advanced position as shown in Figure 5(A) and the outlet port 87 remains closed.

[0053] When the thermal load is approximately nil and the temperature detected by the temperature sensor 34 drops to a predetermined level or lower (a temperature at which frosting can occur in the evaporator 33), the controller C interrupts the supply of electric current to the solenoid coil 43. Thus, transmission of power from the engine E to the compressor is interrupted, which stops the compressor.

[0054] This embodiment has the following effects.

[0055] During operation of the compressor under maximum displacement, the inlet valve mechanism 51 of the electromagnetic valve 50 is fully closed to avoid the flow of gas from the discharge chamber 22 to the crank chamber 5. Accordingly, the gas discharged into the discharge chamber 22 is almost entirely supplied to the external coolant circuit 30, allowing the compressor to operate efficiently.

[0056] When the discharge displacement is shifted from the maximum to the minimum, the spool valve element 83 of the adjusting mechanism 80 moves to the retracted position practically simultaneously with the opening of the inlet valve mechanism 51 of the electromagnetic valve 50 to open the outlet port 87 and the first outlet passage 88. Thus, the flow rate of gas from the discharge chamber 22 to the crank chamber 5 is great to rapidly increase the crank pressure Pc. This results in a rapid shift to the minimum discharge displacement and improves the compressor's response to a demand for a change in the displacement.

[0057] The outlet port 87 and the first outlet passage 88 of the adjusting mechanism 80 are opened only the while the spool valve element 83 moves back and forth a time. This temporary opening feeds a minimum amount of gas to the crank chamber 5 needed to fully increase the crank pressure Pc. That is, excessive delivery of the high-pressure gas to the crank chamber 5 is prevented, and the release of gas from the discharge chamber 22 is thus minimized. Accordingly, the compressor has superior operation efficiency compared to prior art compressors.

[0058] The adjusting mechanism 80 can repeat the operation of automatically supplying gas to the crank chamber 5 any number of times even when the opening and closing of the inlet valve mechanism 51 is repeated in short cycles. Accordingly, even when abrupt changes in the thermal load are repeated, the compressor does not lose control of the discharge displacement. That is, the compressor operates properly under any circumstances.

[0059] The valve body 67 of the outlet valve mechanism 52 can be separated from the second rod 62. Accordingly, when the crank pressure Pc becomes too high, the outlet valve mechanism 52 serves as a differential pressure regulating valve operating independent from the operation of the inlet valve mechanism 51, as shown in Figure 4. Thus, it is guaranteed that the crank pressure Pc will not become too high.

[0060] Figures 6 and 7 show an electromagnetic valve 50 in a second embodiment of the present invention. The differences from the first embodiment shown in Figures 1 to 5(B) will mainly be described.

[0061] As shown in Figures 6 and 7, the adjusting mechanism 80 is incorporated into the valve housing 54 of the electromagnetic valve 50 in this embodiment. More specifically, a chamber for the adjusting mechanism 80 is defined above the inlet valve mechanism 51, and the spool valve element 83 is housed in this chamber to move in the axial direction of the electromagnetic valve 50. The second rod 62 passes through the spool valve element 83 and is movable relative to the valve element 83.

[0062] The inlet chamber 84 is defined under the spool valve element 83. The inlet chamber 84 communicates with the inlet valve chamber 55 via a valve opening 56. The inlet chamber 84 communicates with the crank chamber 5 via an outlet port 87 (corresponding to the port 58 in Figure 2) located in the valve housing 54. A pressure control chamber 85 is defined above the spool valve element 83. The pressure control chamber 85 communicates with the crank chamber 5 via a restriction 90a connecting the pressure control chamber 85 to the valve opening 64, and a third port 65.

[0063] A spring 93 is housed in the pressure control chamber 85. The chambers 84 and 85 communicate with each other via a first restriction 83a (having a diameter greater than that of the restriction 90a) defined in the spool valve element 83. When the spool valve element 83 is located at the advanced position (see Figure 6) and is abutted against a first stopper 91, the outlet port 87 is closed. When the spool valve element 83 is located at the retracted position (see Figure 7) and is abutted against a second stopper 92, the outlet port 87 is opened. The downstream part of the supply passage 28 serves also as the first outlet passage 88 of Figures 5(A) and 5(B).

[0064] If the electromagnetic valve 50 shown in Figures 6 and 7 is incorporated into the compressor of Figure 1, the same actions and effects as in the embodiment shown in Figures 1 to Figure 5(B) are achieved. Particularly, the crank pressure control mechanism is more compact in this embodiment, and installation of this mechanism into the compressor is simplified.

[0065] If enough space for the pressure control chamber 85 is not available in the valve housing 54, a communication hole may be defined in the housing wall partitioning the pressure control chamber 85 to provide an auxiliary chamber of the pressure control chamber 85 within the compressor.

[0066] In Figures 5(A) and 5(B), there may be defined, in place of the first restriction 83a defined in the spool valve element 83, a clearance serving as a first restriction 83a between the inner wall surface of the storage chamber 82 and the circumferential surface of the spool valve element 83.

[0067] While the second spring 69 is housed in the plunger chamber 71 in Figures 2, 3, 6 and 7, the second spring 69 may be housed in the inlet valve chamber 55, as shown in Figure 8.

[0068] The electromagnetic valve 50 having the inlet valve mechanism 51 and the outlet valve mechanism 52 shown in Figures 1 to 8 may be replaced with an electromagnetic valve having no outlet valve mechanism 52 but having an inlet valve mechanism 51 and a solenoid 53. In this case, a fixed restriction 100 is preferably located in the bleed passage 29 connecting the crank chamber 5 and the suction chamber 21. Provided that the flow rate of the blow-by gas leaking from each cylinder bore 1a in the compression stroke into the crank chamber 5 is fA, the flow rate of the gas supplied from the discharge chamber 22 through the inlet valve mechanism 51 and the adjusting mechanism 80 into the crank chamber 5 is fB, and the flow rate of the gas discharged from the crank chamber 5 through the bleed passage 29 into the suction chamber 21 is fC, then the diameter of the fixed restriction 100 may be set to satisfy the following equations: $fC < fA + fB$, when the inlet valve mechanism 51 is opened, and $fC > fA$, when the inlet valve mechanism 51 is closed.

[0069] The present invention may be applied to a variable displacement compressor of the clutchless type, in which power is always transmitted from the external drive source E directly to the drive shaft 6.

Claims

1. A variable displacement compressor for varying the displacement in accordance with a pressure in a crank chanter, characterized by:

a discharge pressure zone, the pressure of which is a discharge pressure;
a supply passage for supplying gas from the discharge pressure zone to the crank chamber;
an inlet valve mechanism located in the supply passage, wherein the inlet valve mechanism opens and closes the supply passage to control the pressure in the crank chamber;
an adjusting mechanism located in the supply passage between the inlet valve mechanism

and the crank chamber, wherein the adjusting mechanism gradually varies the amount of gas that flows from the discharge pressure zone to the crank chamber through the supply passage when the inlet valve mechanism is open.

2. The compressor according to claim 1 characterized in that the adjusting mechanism increases the amount of gas supplied to the crank chamber only before a predetermined time elapses after the inlet valve mechanism opens and restricts the amount of gas after the predetermined time elapses.

3. The compressor according to claims 1 or 2, wherein the adjusting mechanism includes a first passage, a second passage and a movable body for selectively opening and closing the first passage, wherein each of the first passage and the second passage permits the flow of gas from the inlet valve mechanism to the crank chamber, wherein the first passage permits a greater flow of gas than the second passage, and the movable body opens the first passage only before a predetermined time elapses and closes the first passage after the predetermined time elapses.

4. The compressor according to claim 3 characterized in that the movable body moves in accordance with the pressure that acts on the movable body.

5. The compressor according to claims 1 or 2, wherein the adjusting mechanism is characterized by:

an accommodating chamber;
a movable body movably located in the accommodating chamber for separating the accommodating chamber into a first chamber and a second chamber, wherein the first chamber is connected to the inlet valve mechanism through the supply passage;
a restriction passage for connecting the first chamber to the second chamber;
a first outlet passage for conducting gas from the first chamber to the crank chamber;
a second outlet passage for conducting gas from the second chamber to the crank chamber, wherein the first outlet passage permits a greater flow of gas than the second outlet passage, wherein the movable body opens only before a predetermined time elapses after the inlet valve mechanism opens, and the movable body closes the first outlet passage to permit only the flow of gas through the second outlet passage after the predetermined time elapses.

6. The compressor according to claim 5 characterized in that the movable body moves in accordance with the difference between the pressure in the first chamber and the pressure in the second chamber.

7. The compressor according to claims 5 or 6 characterized in that the second outlet passage includes a restricted opening, which has smaller cross-sectional area than the cross-sectional area of the restriction passage.

8. The compressor according to any one of claims 5 to 7 characterized in that the adjusting mechanism includes an urging member for urging the movable body in the direction to close the first outlet passage.

9. The compressor according to claims 1 or 2 the adjusting mechanism is characterized by:

an accommodating chamber;
a movable body located in the accommodating chamber and for separating the accommodating chamber into a first chamber and a second chamber, wherein the first chamber is connected to the inlet valve mechanism through the supply passage;
a restriction passage for connecting the first chamber to the second chamber;
a first outlet passage for conducting gas from the first chamber to the crank chamber, wherein the movable body selectively opens and closes the first outlet passage in accordance with the pressure difference between the pressure in the first chamber and the pressure in the second chamber;
an urging member for urging the movable body in the direction to close the first outlet passage;
a second outlet passage for conducting gas from the second chamber to the crank chamber, wherein the second outlet passage includes a restricted opening, which has smaller cross-sectional area than the cross-sectional area of the restriction passage, wherein the first outlet passage permits a greater flow of gas than the second outlet passage.

10. The compressor according to any one of claims 1 to 9 characterized in that the inlet valve mechanism and the adjusting mechanism are included in a housing.

11. The compressor according to any one of claims 1 to 10, characterized by:

a suction pressure zone, the pressure of which is a suction pressure;
a bleed passage for exhausting gas from the crank chamber to the suction pressure zone;
an outlet valve mechanism for opening or clos-

ing the bleed passage to control the pressure in the crank chamber, wherein, when either the inlet valve mechanism or the outlet valve mechanism opens, the other closes.

12. The compressor according to any one of claims 1 to 11 characterized in that the outlet valve mechanism independently acts in accordance with the pressure difference between the pressure in the crank chamber and the suction pressure to control the pressure in the crank chamber when the inlet valve mechanism opens.

13. The compressor according to any one of claims 11 or 12 characterized in that the inlet valve mechanism, the outlet valve mechanism, and the adjusting mechanism are included in a housing.

Fig.1

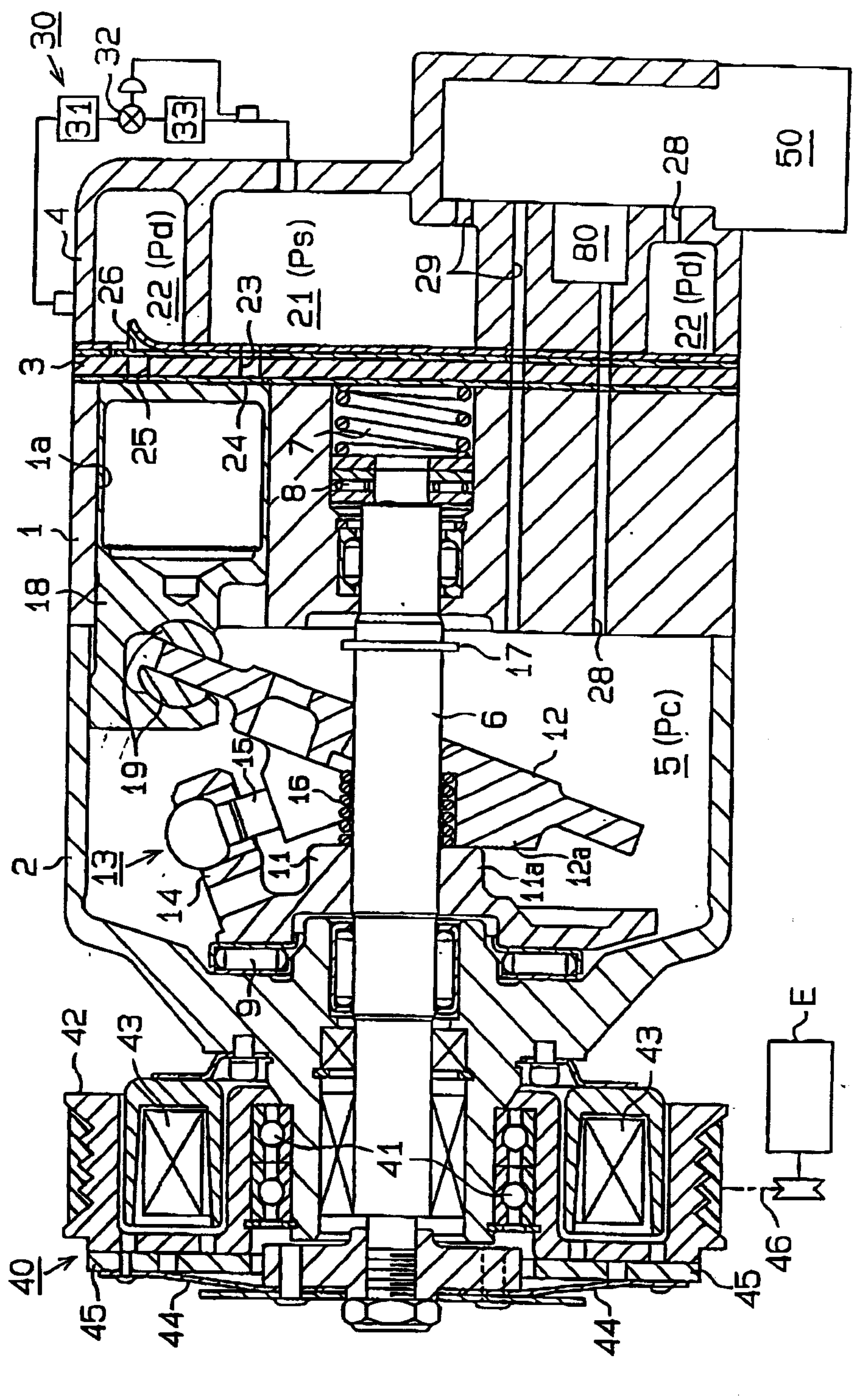

30
31
32
33
4
26
22 (Pd)
21 (Ps)
23
3
29
80
28
50
22 (Pd)
25
24
1a
1
7
8
18
17
28
19
15
6
12
5 (Pc)
16
2
13
14
11
11a
12a
9
42
43
41
E
40
45
44
46

Fig.2

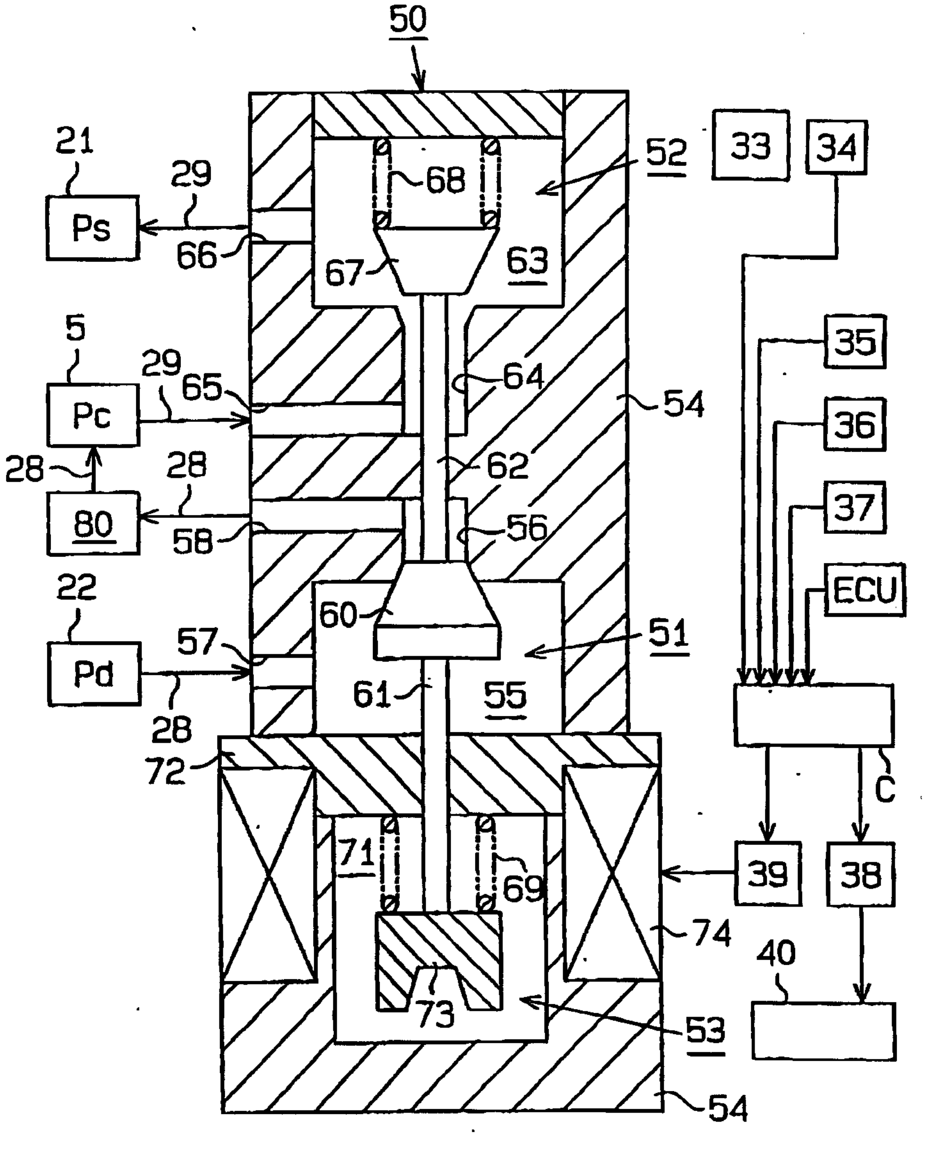

50
21
Ps
29
66
68
52
33
34
67
63
5
29
65
64
Pc
54
28
28
62
80
58
56
35
36
37
ECU
22
60
51
Pd
57
61
55
28
72
C
71
69
39
38
74
40
73
53
54

Fig.3

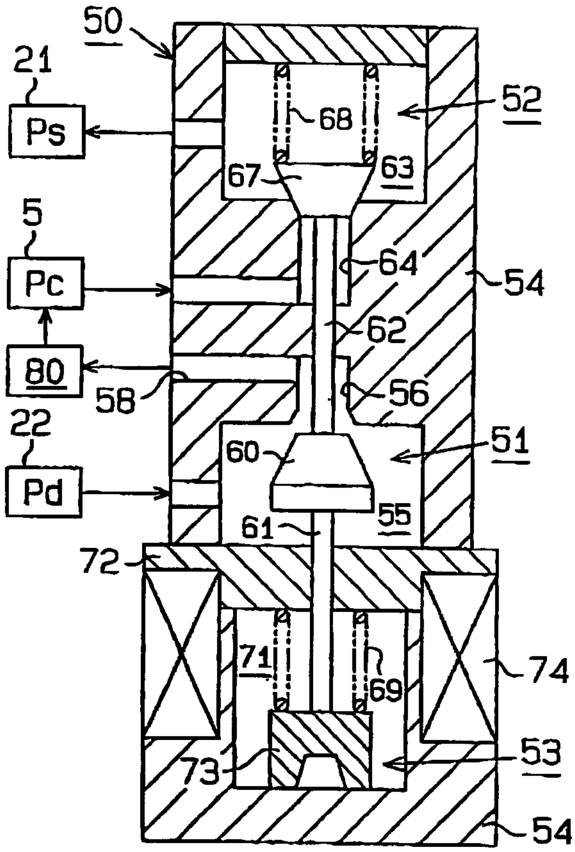

50
21
Ps
5
Pc
80
22
Pd
58
72
68
67
63
52
64
54
62
56
51
60
55
61
71
69
74
73
53
54

Fig.4

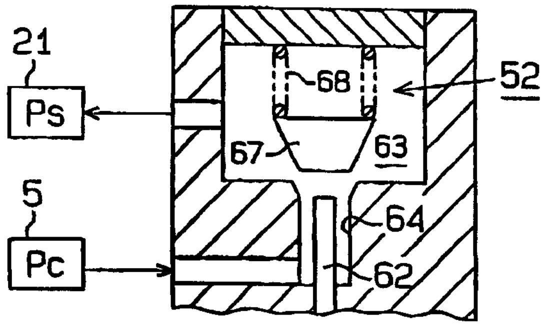

21
Ps
5
Pc
68
52
67
63
64
62

Fig.5(A)

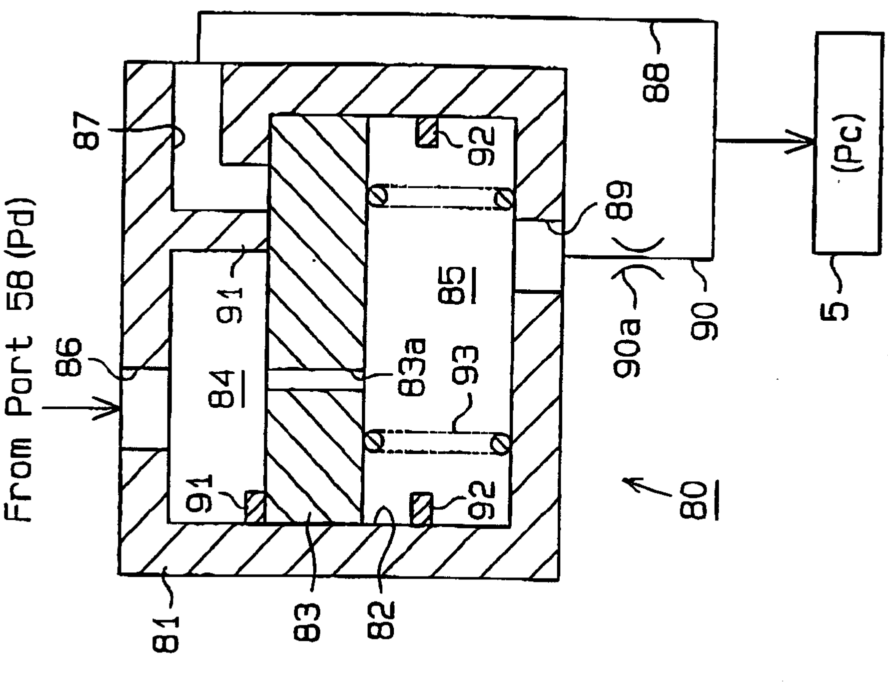

From Port 58 (Pd)
86
87
88
84
91
83a
85
93
89
90a
90
(Pc)
5
91
92
92
80
81
83
82

Fig.5(B)

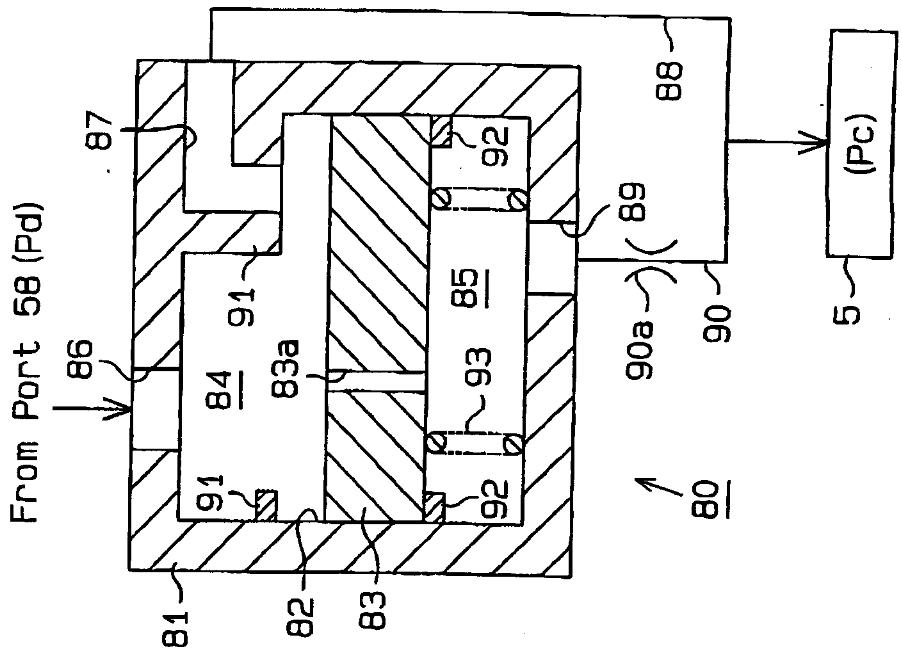

From Port 58 (Pd)
86
87
88
91
84
83a
85
93
89
90a
90
(Pc)
5
91
92
92
80
81
82
83

Fig.6

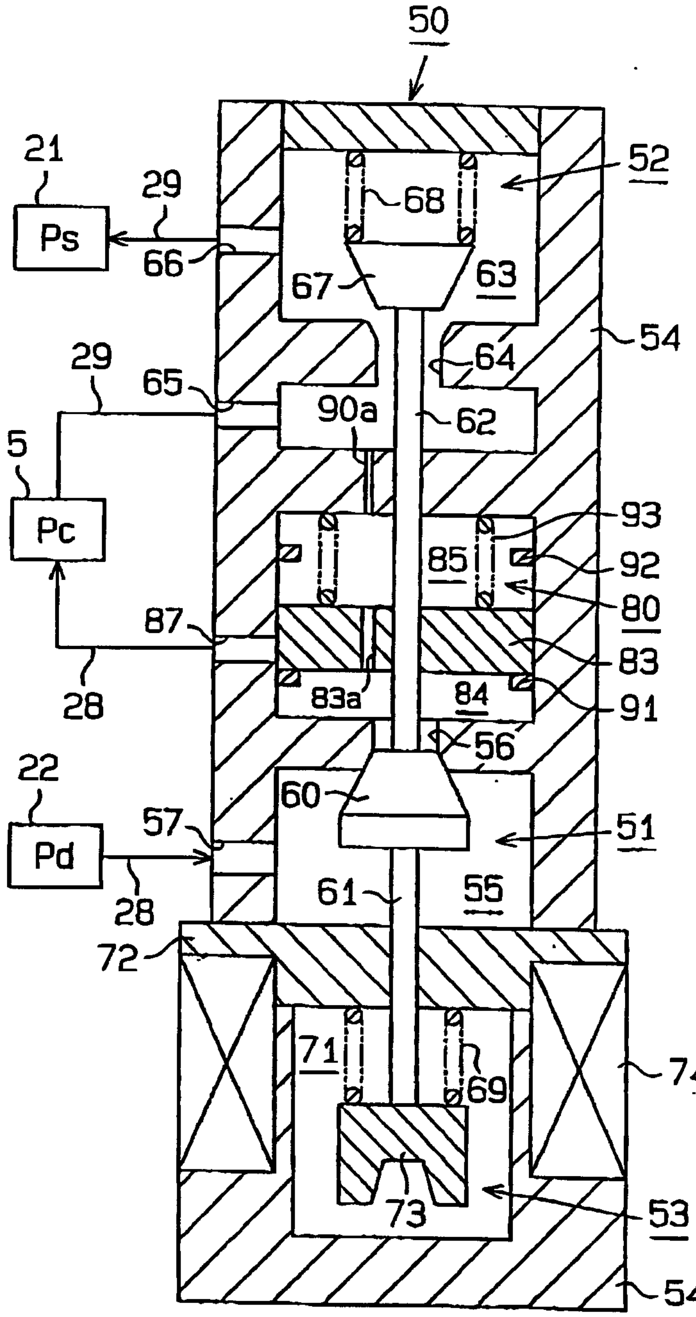

50
52
21
29
Ps
68
66
67
63
54
29
64
65
90a
62
5
Pc
93
85
92
80
87
83
28
83a
84
91
56
22
60
57
51
Pd
28
61
55
72
71
74
69
73
53
54

Fig.7

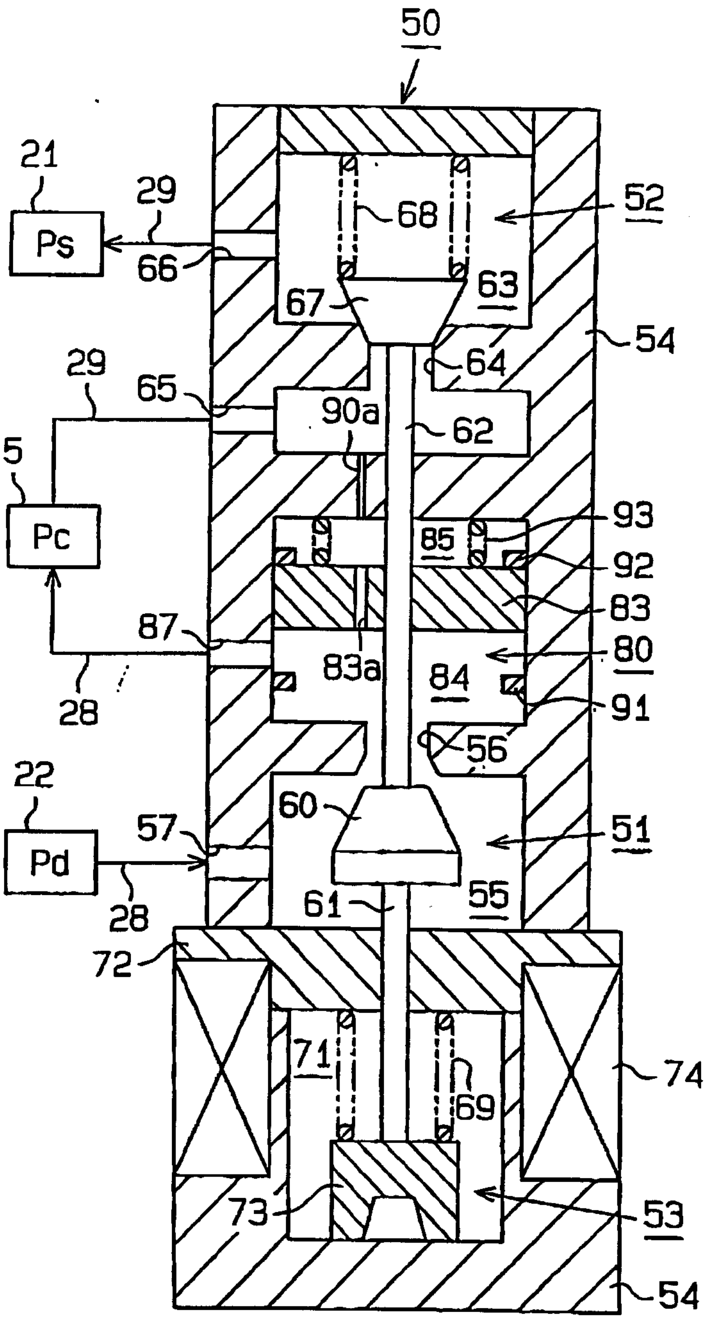

50
21
Ps
29
66
68
52
63
67
54
29
65
90a
64
62
5
Pc
93
85
92
83
87
80
83a
84
28
91
56
22
60
51
57
Pd
28
55
61
72
71
74
69
73
53
54

Fig.8

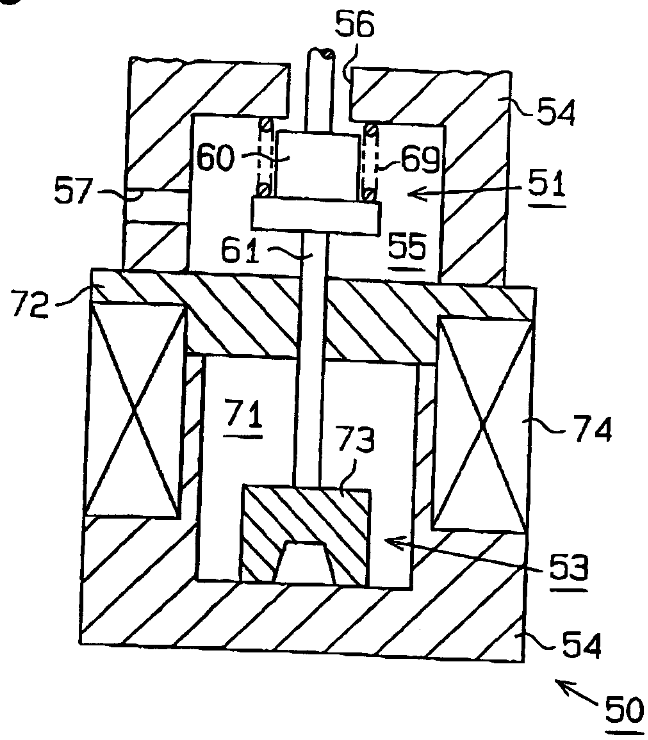
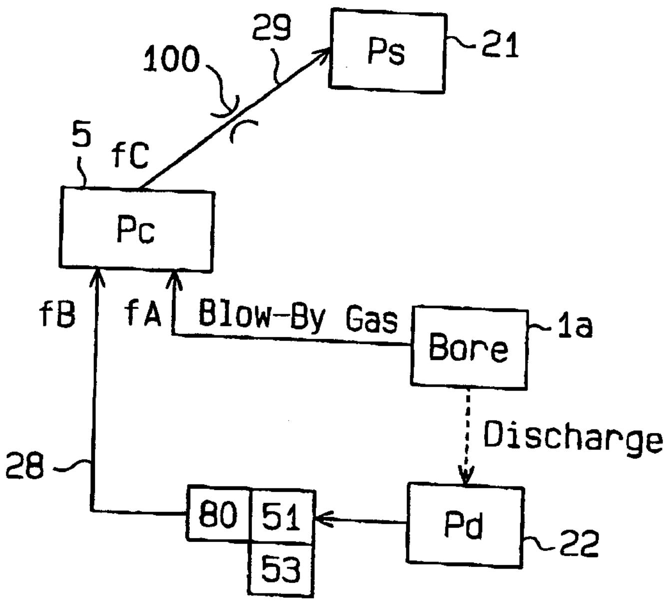

56
54
60
69
51
57
61
55
72
71
73
74
53
54
50

Fig.9


29
Ps
21
100
5
fC
Pc
fB
fA
Blow-By Gas
Bore
1a
Discharge
28
80
51
53
Pd
22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/00650

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 F04B27/08 F04B27/14

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)
Int.Cl^7 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	1926-2000	Toroku Jitsuyo Shinan Koho	1994-2000
Kokai Jitsuyo Shinan Koho	1971-2000	Jitsuyo Shinan Toroku Koho	1996-2000

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.
A	JP, 63-285276, A (Toyoda Automatic Loom Works, Ltd.), 22 November, 1988 (22.11.88), Full text (Family: none)	1~13
A	JP, 3-9087, A (Toyoda Automatic Loom Works, Ltd.), 16 January, 1991 (16.01.91), Full text (Family: none)	1~13

☐ 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 document 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
19 May, 2000 (19.05.00)	30 May, 2000 (30.05.00)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)