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

(11) **EP 1 967 734 A1**

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

(43) Date of publication:
10.09.2008 Bulletin 2008/37

(21) Application number: **06843248.3**

(22) Date of filing: **26.12.2006**

(51) Int Cl.:
F04C 18/16 *(2006.01)* ***F04C 25/02*** *(2006.01)*
F04C 29/02 *(2006.01)*

(86) International application number:
PCT/JP2006/325864

(87) International publication number:
WO 2007/074807 (05.07.2007 Gazette 2007/27)

(84) Designated Contracting States:
DE GB

(30) Priority: **26.12.2005 JP 2005372225**

(71) Applicant: **KABUSHIKI KAISHA TOYOTA JIDOSHOKKI**
Kariya-shi, Aichi 448-8671 (JP)

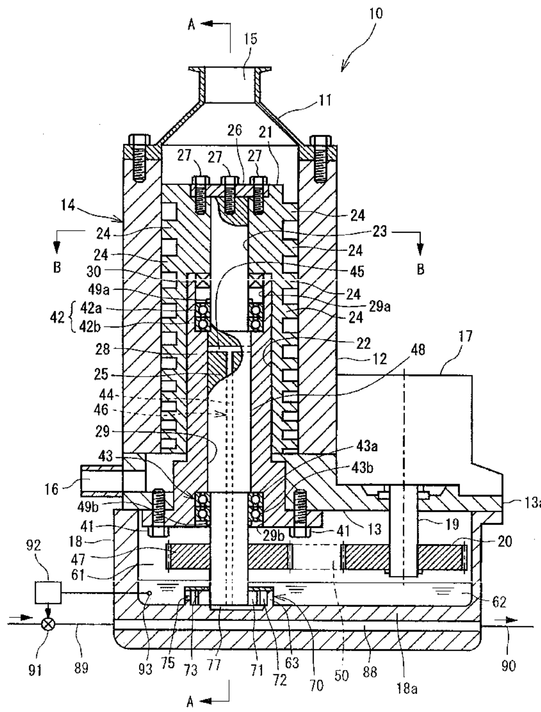
(72) Inventors:
- **YAMAMOTO, Shinya**
  Aichi 448-8671 (JP)
- **KOSHIZAKA, Ryosuke**
  Aichi 448-8671 (JP)
- **ISHIHARA, Kentaro**
  Aichi 448-8671 (JP)
- **INAGAKI, Masahiro**
  Aichi 448-8671 (JP)
- **IZAWA, Yuya**
  Aichi 448-8671 (JP)

(74) Representative: **TBK-Patent**
Bavariaring 4-6
80336 München (DE)

(54) **SCREW-TYPE FLUID MACHINE**

(57) A vacuum pump includes rotary shafts connected to a pair of screw-type rotors, respectively, and a pair of shaft retainers extending in the housing. Each shaft retainer supports the corresponding rotary shaft by means of a proximal bearing portion and a distal bearing portion. Each pair of the proximal and distal bearing portions are fixed in the axial direction with respect to the corresponding rotary shaft and shaft retainer. Lubricant oil is stored in an oil storage space in a gear case attached to the housing. A cooling water passage through which cooling water to cool the lubricant oil passes is formed in the gear case. A solenoid valve controls the flow rate of cooling water in the cooling water passage. A temperature sensor is provided in the oil storage space and detects the temperature of the lubricant oil. A controller controls the solenoid valve in accordance with the temperature detected by the temperature sensor, so that the temperature of the lubricant oil in the oil storage space is kept constant. With this configuration, when the bearing portions are fixed in the axial direction with respect to the rotary shafts and the shaft retainers, it is possible to prevent load from being applied to the bearing portions in the axial direction.

Fig.1



EP 1 967 734 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a screw-type fluid machine such as a vacuum pump, that is used in, for example, a semiconductor manufacturing process.

BACKGROUND ART

[0002] For example, a screw-type vacuum pump described in Patent Document 1 has been known as a screw-type fluid machine. The screw-type vacuum pump according to Patent Document 1 includes a pair of screw-shaped rotors, which are adjacent to and meshed with each other, in the casing. Each rotor has a rotary shaft. The rotary shafts are supported with respect to the casing, which operates as a shaft retainer, with upper bearings and lower bearings.

[0003] A synchronous gear is fixed to each rotary shaft, and the synchronous gears are meshed with each other. A lubricant oil passage extending in the axial direction is formed in the interior of the each rotary shaft, and the lubricant oil passage functions as a centrifugal pump. The lubricant oil passage has an inlet open to the lower end of the rotary shaft and an outlet open to the circumferential surface of the rotary shaft above the upper bearing. A heat exchanger is provided near the inlet of the lubricant oil passage. Lubricant oil is stored in the casing, and the lower end of the rotary shaft is immersed in the lubricant oil stored therein. Further, a cooling water pipe is provided in the casing, and heat exchange takes place between the cooling water and the lubricant oil in the heat exchanger.

[0004] As the vacuum pump is driven, the centrifugal pump draws up lubricant oil stored in the casing. The lubricant oil is subjected to heat exchange and cooled down by the heat exchanger when being drawn up by the centrifugal pump. The lubricant oil thus drawn up comes out through the outlet of the lubricant oil passage and flows down to the upper bearing to cool the upper bearing. After that, the lubricant oil flows down from the upper bearing along the rotary shaft and is again stored in the casing. With such circulation of the lubricant oil, the upper and lower bearings, the rotary shaft, and other members, are cooled. If the rotary shaft is thermally expanded due to, for example, load is applied to the bearings, by which the rotary shaft is supported with respect to the casing, in the axial direction. However, since the bearings and rotary shafts are cooled by the lubricant oil, such thermal expansion is suppressed, and the load on the bearings is reduced.

[0005] However, by only cooling the lubricant oil merely using the heat exchanger, it is impossible to finely adjust the temperature of the lubricant oil in accordance with the running state of the vacuum pump. Therefore, practically, the thermal expansion of the rotary shaft cannot be sufficiently suppressed, and it is not possible to sufficiently suppress the load applied to the bearings in the axial direction.

[0006] If the bearings are provided between the casing and the rotary shaft so as to allow displacement of the rotary shaft in the axial direction with respect to the casing, load resulting from thermal expansion of the rotary shafts can be prevented from being applied to the bearings in the axial direction. However, when such a configuration is used, it is impossible to prevent the rotary shafts from being subjected to lateral sway and longitudinal sway, which likely to result in vibrations and noises.

Patent Document 1: Japanese Laid-Open Patent Publication No. 4-314991

DISCLOSURE OF THE INVENTION

[0007] It is an objective of the present invention to provide a screw-type fluid machine capable of preventing load from being applied to bearings in the axial direction even when the bearings are fixed in the axial direction with respect to rotary shafts and a shaft retainer.

[0008] In order to achieve the above objective and in accordance with one aspect of the present invention, a screw-type fluid machine is provided that includes a housing, a pair of screw-shaped rotors which are accommodated in the housing and are meshed with each other, a pair of rotary shafts which are connected to both rotors so as to become coaxial with the rotors respectively, and a pair of cylindrical shaft retainers extending in the housing. Each rotary shaft has an end portion protruding from the housing. Each shaft retainer has a first end portion and a second end portion, and also has a through hole into which one of the rotary shafts is inserted. The first bearing is mounted in the through hole at the first end portion, and the second bearing is mounted in the through hole at the second end portion. Each pair of the first and second bearings supports the corresponding rotary shaft rotatably with respect to the shaft retainer. The first and second bearings are fixed in the axial direction with respect to the corresponding rotary shafts and the shaft retainers. Synchronous gears are provided at the end portions of both rotary shafts protruding from the housing, respectively. A gear case accommodates the synchronous gears, and the gear case defines an oil reservoir space in which lubricant oil can be stored. A cooling portion cools down the lubricant oil using a cooling fluid. The flow rate changing portion controls the flow rate of the cooling fluid. A temperature sensor is provided in the oil reservoir space and detects the temperature of the lubricant oil. A control portion controls the flow rate changing portion in accordance with the temperature detected by the temperature sensor so that the temperature of lubricant oil in the oil reservoir space is kept constant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 is a longitudinally cross-sectional view of a vacuum pump according to one embodiment of the present invention;

Fig. 2 is a cross-sectional view taken along line A-A of the vacuum pump of Fig. 1;

Fig. 3 is an enlarged view showing a major portion of a proximal bearing portion and a distal bearing portion in the vacuum pump of Fig. 1;

Fig. 4 is a cross-sectional view taken along line B-B of the vacuum pump of Fig. 1; and

Fig. 5 is an enlarged sectional view of an oil feed pump in the vacuum pump of Fig. 1.

BEST MODE FOR CARRYING OUT THE INVENTION

[0010] One embodiment according to the present invention will now be described, with reference to Figs. 1 to 5. As shown in Fig. 1, a screw-type fluid machine according to the present embodiment is a screw-type vacuum pump 10 which is vertically placed and used for semiconductor manufacturing (hereinafter simply referred to as a "vacuum pump"). The vacuum pump 10 has a housing 14 having an upper housing member 11, a rotor housing member 12, and a lower housing member 13. The housing 14 forms the shell of the vacuum pump 10.

[0011] In detail, the upper housing member 11 is connected to the upper end of the rotor housing member 12, and the lower housing member 13 is connected to the lower end of the rotor housing member 12. A suction port 15 to draw in a compressive fluid is formed in the upper housing member 11 so as to communicate with the interior of the housing 14. The lower housing member 13 is provided with a discharge port 16 to discharge the compressive fluid. The discharge port 16 communicates with the interior of the housing 14. Also, the lower housing member 13 is provided with an extension part 13a caused to extend sideways, and a drive motor 17 operating as a drive source is installed on the extension part 13a. Furthermore, a gear case 18 to cover the lower housing member 13 including the extension part 13a from downward thereof is connected to the lower housing member 13.

[0012] As shown in Fig. 2, a screw-type male rotor 21 and a screw-type female rotor 31, which are meshed with each other, are accommodated in the housing 14. An operation chamber is formed by the rotors 21, 31 and the housing 14. The male rotor 21 has an insertion hole 22 extending from the discharge port 16 toward the suction port 15 and an connection hole 23, the diameter of which is smaller than that of the insertion hole 22, extending upward from the upper end of the insertion hole 22. A rotary shaft 25 passing through the lower housing member 13 is inserted into the connection hole 23. The male rotor 21 and the rotary shaft 25 are connected to each other by using a stop plate 26 and a connection bolt 27. Accordingly, the male rotor 21 and the rotary shaft 25 rotate integrally. Similarly, the female rotor 31 shown in Fig. 2 is provided with an insertion hole 32 and a connection hole 33, and is connected to a rotary shaft 35 by using a stop plate 36 and a connection bolt 37. Each of the respective rotors 21 and 31 is coaxial with the corresponding one of the rotary shafts 25 and 35.

[0013] The lower housing member 13 has a pair of cylindrical shaft retainers 28, 38 extending upward, and as shown in Fig. 2, the proximal portions of the shaft retainers 28, 38 are linked with each other and integrated. In this embodiment, the shaft retainers 28, 38 are fixed to the lower housing member 13 by fixing bolts 41. The shaft retainer 28 is inserted into the insertion hole 22 of the male rotor 21, and a slight space is formed between the outer circumferential surface of the shaft retainer 28 and the inner-circumferential surface of the insertion hole 22. The shaft retainer 38 is inserted into the insertion hole 32 of the female rotor 31, and a slight space is also formed between the outer circumferential surface of the shaft retainer 38 and the inner circumferential surface of the insertion hole 32.

[0014] A through hole 29 extending in the axial direction is formed at the center of the shaft retainer 28, and the rotary shaft 25 for the male rotor 21 is inserted into the through hole 29. A pair of upper and lower bearing portions 42, 43 consisting of roller bearings are provided between the rotary shaft 25 and the shaft retainer 28. The bearing portions 42, 43 are disposed at the upper and lower parts of the shaft retainer 28. In this embodiment, the upper bearing portion 42 is a distal bearing portion or a second bearing portion, and the lower roller bearing 43 is a proximal bearing portion or a first bearing portion. An upper large diameter hole 29a having a larger diameter than the diameter of the through hole 29 is formed at the upper end portion (the second end portion) of the shaft retainer 28, continuous to the through hole 29. The distal bearing portion 42 is disposed in the upper large diameter hole 29a. Also, the portion between the distal bearing 42 and the proximal bearing 43 at the rotary shaft 25 has a slightly larger diameter than that of the upper and lower parts of the rotary shaft 25. As shown in Fig. 3, the portion of the rotary shaft 25, the diameter of which changes, forms a distal step portion 25a and a proximal step portion 25b.

[0015] As shown in Figs. 1 and 2, a sealing member 30 is located between the rotary shaft 25 and the shaft retainer 28 at a position above the distal bearing portion 42. A lower large diameter hole 29b having a larger diameter than that of the through hole 29 is provided at the lower end portion (the first end portion) of the shaft retainer 28, continuous to the through hole 29. The proximal bearing portion 43 is disposed in the lower large diameter hole 29b.

[0016] These bearing portions 42, 43 are provided to rotatably support the rotary shaft 25 with respect to the shaft retainer 28. In the embodiment, each of the distal bearing portion 42 and the proximal bearing portion 43 is structured by stacking two roller bearings each one being a single row.

[0017] A further detailed description will now be given of the distal bearing portion 42. The distal bearing portion 42 is composed of a combination of two angular ball bearings 42a, 42b. As shown in Fig. 3, both bearings 42a, 42b are disposed in the upper large diameter hole 29a in a state of Duplex Back-to-back. The outer rings of both bearings 42a, 42b are pressure-fitted to the upper large diameter hole 29a and fixed to the shaft retainer 28. In addition, the inner rings of both bearings 42a, 42b are pressure-fitted to the rotary shaft 25.

[0018] The inner ring of the angular ball bearing 42b is pressed against the distal step portion 25a of the rotary shaft 25, and the inner ring of the angular ball bearing 42a is pressed against the inner ring of the angular ball bearing 42b by a nut 49a screwed in the rotary shaft 25. As a result, the rolling elements of the angular ball bearings 42a, 42b are in contact with the inner and outer rings without any space in either of the axial direction or the radial direction.

[0019] On the other hand, as shown in Fig. 3, the angular ball bearings 43a, 43b are disposed at the lower large diameter hole 29b at the proximal bearing portion 43 in a state of Duplex Back-to-back. The outer rings of the bearings 43a, 43b are pressure-fitted to the lower large diameter hole 29b and are fixed to the shaft retainer 28. The inner ring of the angular ball bearing 43a is pressed against the proximal step portion 25b of the rotary shaft 25, and the inner ring of the angular ball bearing 43b is pressed against the inner ring of the angular ball bearing 43a by a nut 49b screwed in the rotary shaft 25. Therefore, the rolling elements of the angular ball bearings 43a, 43b are in contact with the inner and outer rings without any space in either of the axial direction or the radial direction.

[0020] Since the distal bearing portions 42 and the proximal bearing portions 43 are each composed of two angular ball bearings in the state of Duplex Back-to-back, the rotary shaft 25 does not move in the axial direction and the radial direction with respect to the shaft retainer 28. That is, the distal bearing portion 42 and the proximal bearing portion 43 are fixed in the axial direction by means of nuts 49a, 49b and the step portions 25a, 25b.

[0021] These angular ball bearings 42a, 42b, 43a, 43b secure a slight space between the outer circumferential surface of the rotary shaft 25 and the inner circumferential surface of the through hole 29 of the shaft retainer 28. The space forms a lubricant oil recovery passage 48 (hereinafter, simply referred to as an oil recovery passage 48). The oil recovery passage 48 causes lubricant oil 62, which is a cooling medium, to be brought into contact with the rotary shaft 25 and the shaft retainer 28, which are objects to be cooled down. The oil recovery passage 48 is also a passage that supplies lubricant oil 62 to the gear case 18.

[0022] On the other hand, a long conduit 44 extending along the axis of the rotary shaft 25 is formed in the rotary shaft 25. The long conduit 44 reaches the underside of the distal bearing portion 42 from the lower end of the rotary shaft 25. A short conduit 45 extending in the radial direction of the rotary shaft 25 is formed in the rotary shaft 25 below the distal bearing portion 42. The upper end of the long conduit 44 is located below the distal bearing portion 42, and is connected to the short conduit 45. The short conduit 45 is made open to the circumferential surface of the rotary shaft 25 at a position below the distal bearing portion 42 so as to communicate with the oil recovery passage 48. The long conduit 44 and the short conduit 45 compose an oil feed passage 46 that supplies lubricant oil 62 to the oil recovery passage 48. The oil feed passage 46 and the oil recovery passage 48 compose an oil circulation passage.

[0023] In the above, a description has been given of respective elements such as the shaft retainer 28 at the male rotor 21, rotary shaft 25, bearing portions 42, 43. Respective elements at the female rotor 31 basically have the same configuration as those at the male rotor 21. That is, as shown in Fig. 2, the rotary shaft 35 is inserted into the through hole 39 of the shaft retainer 38. The shaft retainer 38 is provided with an upper large diameter hole 39a and a lower large diameter hole 39b as in the shaft retainer 28. A distal bearing portion 52 and a proximal bearing portion 53 are disposed in the upper large diameter hole 39a and the lower large diameter hole 39b, respectively. The bearing portions 52, 53 are disposed between the rotary shaft 35 and the shaft retainer 38.

[0024] A distal bearing portion 52 is composed of two angular ball bearings 52a, 52b in a state of Duplex Back-to-back as in the distal bearing portion 42 of the male rotor 21, and is pushed down by a nut 59a. Further, a sealing member 40 is disposed at a position above the distal bearing portion 52. The proximal bearing portion 53 is composed of two angular ball bearings 53a, 53b in a state of Duplex Back-to-back as in the proximal bearing portion 43 of the male rotor 21, and is pushed upward by a nut 59b.

[0025] In addition, an oil feed passage 56 composed of a long conduit 54 and a short conduit 55 is formed in the rotary shaft 35 of the female rotor 31. Further, a space that forms an oil recovery passage 58 is formed between the rotary shaft 35 and the shaft retainer 38. The axial diameters of the rotary shafts 25, 35 are identical to each other, and the distal bearing portions 42, 52 and the proximal bearing portions 43, 53 use angular ball bearings of the same specification.

[0026] A detailed description will now be given of the male rotor 21. As shown in Fig. 4, the male rotor 21 has five teeth 24, and these teeth 24 are disposed equidistant in the circumferential direction of the male rotor 21. Also, the teeth 24 spirally extend from the upper end of the male rotor 21 to the lower end thereof. And, as shown in Fig. 2, the teeth 24 are formed so that the lead angle decreases from the upper end toward the lower end.

[0027] On the other hand, tooth grooves 34 in the female rotor 31 are formed so as to correspond to the teeth 24 of the male rotor 21 as shown in Fig. 4, and the number of the tooth grooves 34 is six. That is, since the number of the teeth 24 of the male rotor 21 is fewer than the number of the tooth grooves 34 of the female rotor 31, the rotation speed of the male rotor 21 becomes faster than that of the female rotor 31 when both rotors 21 and 31 synchronously rotate, and the rotation speed of the female rotor 31 becomes lower than that of the male rotor 21. Such screw-type rotors 21 and 31 are called a gradual change type.

[0028] As shown in Figs. 1 and 2, the rotary shaft 25 of the male rotor 21 extends so as to pass through the lower housing member 13, and the lower end of the rotary shaft 25 is positioned in the gear case 18. The portion located in the gear case 18 of the rotary shaft 25 is provided with a synchronous gear 47. On the other hand, the rotary shaft 35 of the female rotor 31 extends so as to pass through the lower housing member 13 as well, and the lower end of the rotary shaft 35 is positioned in the gear case 18. The portion located in the gear case 18 of the rotary shaft 35 is provided with a synchronous gear 57. Both synchronous gears 47, 57 are meshed with each other.

[0029] As shown in Fig. 1, the synchronous gear 47 at the male rotor 21 is meshed with an intermediate gear 50 secured in the gear case 18. The intermediate gear 50 is meshed with a drive gear 20 attached to the drive shaft 19 of the drive motor 17 in the gear case 18. An oil storage chamber 61 that composes an oil reservoir space is formed at the lower part of the gear case 18, and lubricant oil 62 is stored in the oil storage chamber 61.

[0030] A cylindrical projection 63 is formed at the portion of the bottom plate 18a of the gear case 18, which is opposite to the lower end of the rotary shaft 25. As shown in Fig. 5, the projection 63 defines a circular hole 63a having a bottom. A trochoidal oil feed pump 70 operating as an oil feed portion is disposed in the circular hole 63a. The oil feed pump 70 includes an outer rotor 72 consisting of an inner-toothed gear and an inner rotor 71 consisting of an outer-toothed gear. The inner rotor 71 is disposed inside the outer rotor 72. The outer circumferential surface of the outer rotor 72 is rotatably fitted to the inner circumferential surface of the circular hole 63a. The lower end of the rotary shaft 25 is fitted in and fixed in the through hole 71a of the inner rotor 71.

[0031] The inner rotor 71 is eccentric with respect to the outer rotor 72. When the inner rotor 71 rotates, the outer rotor 72 also rotates therewith. An opening at the upper end of the cylindrical projection 63 is blocked by an upper cover 73, and the upper cover 73 covers the inner rotor 71 and the outer rotor 72. In addition, the oil feed pump 70 has an oil suction portion 75 and an oil discharge portion 76. The oil suction portion 75 communicates with the oil storage chamber 61. The oil discharge portion 76 communicates with the oil feed passage 46 of the rotary shaft 25 via a guide passage 77 formed on the bottom of the circular hole 63a.

[0032] As the rotary shaft 25 rotates, lubricant oil 62 stored in the oil storage chamber 61 is drawn in the oil feed pump 70 through the oil suction portion 75, in detail, drawn in a space between the rotors 71 and 72. The lubricant oil is conveyed through the space between the rotors 71 and 72 and reaches the oil discharge portion 76. The oil is then fed from the oil discharge portion 76 to the oil feed passage 46 through the guide passage 77.

[0033] On the other hand, as shown in Fig. 2, a cylindrical projection 64 is formed at the portion of the bottom plate portion 18a of the gear case 18, which is opposite to the lower end of the rotary shaft 35. The projection 64 defines the circular hole 64a having a bottom. A trochoidal oil feed pump 80 operating as an oil feed device is disposed in the circular hole 64a. Although the structure of the oil feed pump 80 is not illustrated in detail, the structure is equivalent to the oil feed pump 70. That is, the oil feed pump 80 includes an inner rotor 81 and an outer rotor 82. The outer circumferential surface of the outer rotor 82 is rotatably fitted to the inner circumferential surface of the circular hole 64a, and the inner rotor 81 is linked with the rotary shaft 35. The inner rotor 81 and the outer rotor 82 are covered by an upper cover 83. Also, although not illustrated, the oil feed pump 80 has an oil suction portion communicating with the oil storage chamber 61 and an oil discharge portion communicating with the oil feed passage 56 through a guide passage 87. When the inner rotor 81 rotates together with the rotary shaft 35, the outer rotor 82 rotates, accordingly, and the lubricant oil 62 in the oil storage chamber 61 is fed to the oil feed passage 56 through the oil suction portion, a space between both rotors 81 and 82, the oil discharge portion, and the guide passage 87.

[0034] In addition, the vacuum pump 10 according to the present embodiment has a configuration to cool the lubricant oil 62 stored in the gear case 18. That is, a plurality of cooling water passages 88 through which cooling water operating as a cooling fluid passes are formed in the bottom plate portion 18a of the gear case 18. The cooling water passages 88 extend so as to pass through the bottom plate 18a. Since cooling water is caused to pass through the cooling water passage 88, the lubricant oil 62 stored in the gear case 18 is then cooled. The cooling water passages 88 function as a cooling portion to cool down the lubricant oil 62 by using the cooling fluid.

[0035] As shown in Fig. 1, the upstream part of the cooling water passage 88 is connected to an upstream pipe 89 provided with a solenoid valve 91 as a flow rate changing portion, and the downstream part of the cooling water passage 88 is connected to a downstream pipe 90. The solenoid valve 91 is controlled so as to open and close the upstream pipe 89 by a controller 92 operating as a control portion. The controller 92 is connected to a temperature sensor 93 that directly measures the temperature of the lubricant oil 62 in the gear case 18. The temperature sensor 93 is disposed in the gear case 18, that is, in the oil storage chamber 61. The controller 92 controls the solenoid valve 91 based on detection signals from the temperature sensor 93 so that the temperature of the lubricant oil 62 in the gear case 18 is maintained to be constant.

[0036] Next, a description is given of operations of the vacuum pump 10 according to the embodiment. When the drive motor 17 is rotated, rotation of the drive motor 17 is transmitted to the synchronous gear 47 of the male rotor 21 via the drive gear 20 and the intermediate gear 50. Thus, the synchronous gears 47, 57 rotate in synchronization with each other, and the rotors 21, 31 rotate along with the rotary shafts 25, 35. Since the rotors 21 and 31 rotate in a state where the teeth 24 of the male rotor 21 are engaged with the tooth grooves 34 of the female rotor 31, a compressive fluid is drawn in the operation chamber through the suction port 15. The compressive fluid drawn in the operation chamber is conveyed to the discharge port 16 while being compressed by the rotors 21 and 31, and is discharged through the discharge port 16. If the suction port 15 is connected to a closed space such as a chamber or a vessel, the closed space can be made in a vacuum state.

[0037] When the vacuum pump 10 is operating, the rotary shafts 25, 35 are caused to rotate at a high speed in directions opposed to each other. Oil feed pumps 70, 80 secured at the end portion of the rotary shaft 25, 35 draw in lubricant oil 62 stored in the oil storage chamber 61 through respective oil suction portions and discharge the same through the respective oil discharge portions. Discharged lubricant oil 62 flows into the lower ends of the long conduits 44, 54 of the rotary shafts 25, 35 through the guide passages 77, 87 communicating with the respective oil discharge portions, and reaches the underside of the distal bearing portions 42, 52, passing through the short conduits 45, 55.

[0038] When the lubricant oil 62 that has reached the underside of the distal bearing portions 42, 52 passes through the oil recovery passages 48, 58 and is oriented downward, it cools the rotary shafts 25, 35 and the shaft retainers 28, 38. By the rotary shafts 25, 35 and the shaft retainers 28, 38 being cooled down, a difference in the temperature between the rotary shafts 25, 35 and the shaft retainers 28, 38 is suppressed. The lubricant oil 62 is recovered in the oil storage chamber 61 in the gear case 18 after having cooled the rotary shafts 25, 35 and the shaft retainers 28, 38. And, the lubricant oil 62 is conveyed from the oil storage chamber 61 to the oil feed pump 70, 80 again, and the same action as above is repeated. Further, the lubricant oil 62 lubricates the synchronous gears 47, 57 via the synchronous gears 47, 57 on the way of being recovered into the oil storage chamber 61.

[0039] Also, the lubricant oil 62 stored in the gear case 18 is cooled by cooling water passing through the cooling water passage 88. That is, in the present embodiment, the lubricant oil 62 is cooled by using cooling water so that the temperature of the lubricant oil 62 supplied for cooling by actions of the oil feed pumps 70, 80 is kept constant. In detail, the controller 92 monitors the temperature of the lubricant oil 62 by means of the temperature sensor 93, and controls the solenoid valve 91 so that the temperature of the lubricant oil 62 is maintained at a preset cooling temperature. The controller 92 opens and closes the solenoid valve 91 in accordance with the temperature of the lubricant oil 62, which is detected by the temperature sensor 93, and adjusts the flow of the cooling water in the cooling water passage 88. That is, the controller 92 opens the solenoid valve 91 when the temperature of the lubricant oil 62 is likely to rise, and prevents the temperature rise of the lubricant oil 62 in the gear case 18 by causing cooling water to flow through the cooling water passages 88. In addition, the controller 92 closes the solenoid valve 91 when the temperature of the lubricant oil 62 is likely to lower, and does not cool the lubricant oil 62 by cooling water by not causing the cooling water to flow through the cooling water passages 88. In this case, the temperature of the lubricant oil 62 stored in the oil storage chamber 61 is prevented from being lowered by the heat of the lubricant oil 62 stored in the oil storage chamber 61.

[0040] By causing the lubricant oil 62, which is kept at a constant temperature, to pass through the oil recovery passages 48, 58, a difference in temperature between the rotary shafts 25, 35 and the shaft retainers 28, 38 can be preferably suppressed, and thermal expansion of the rotary shafts 25, 35 is prevented from occurring. Therefore, it is possible to reliably prevent load generated by thermal expansion of the rotary shafts 25, 35 from being applied to the bearings 42a, 42b, 43a, 43b, 52a, 52b, 53a, and 53b in the axial direction.

[0041] The vacuum pump 10 according to the present embodiment has the following advantages.

(1) The controller 92 controls the solenoid valve 91 based on a detection result of the temperature of lubricant oil 62 by the temperature sensor 93. Therefore, the flow rate of cooling water is adjusted so that the lubricant oil 62 stored in the oil storage chamber 61 is kept at a constant temperature. By causing • the lubricant oil 62, the temperature of which is kept constant, to pass through the oil recovery passages 48, 58, it is possible to cool the rotary shafts 25, 35 and the shaft retainers 28, 38. Consequently, it is possible to prevent a difference in temperature from occurring between the rotary shaft 25 and the shaft retainer 28 and to prevent a difference in temperature from occurring between the rotary shaft 35 and the shaft retainer 38.

(2) The angular ball bearings 42a, 42b, 43a, 43b, 52a, 52b, 53a, and 53b are fixed immovably in the axial direction with respect to the rotary shafts 25, 35 and the shaft retainers 28, 38. However, in the present embodiment, by preventing a difference in temperature from occurring between the rotary shafts 25, 35 and the shaft retainers 28, 38, thermal expansion that results in displacement of the rotary shafts 25, 35 in the axial direction with respect to the shaft retainers 28, 38 is prevented from occurring.

Accordingly, it becomes possible to reliably prevent load from being applied to the bearings 42a, 42b, 43a, 43b, 52a, 52b, 53a, and 53b in the axial direction.

(3) Since load is prevented from being applied to the respective bearings 42a, 42b, 43a, 43b, 52a, 52b, 53a, and 53b, the reliability of the respective bearings is improved, and the power consumption of the vacuum pump 10 is reduced.

(4) Since load is prevented from being applied to the respective bearings 42a, 42b, 43a, 43b, 52a, 52b, 53a, and 53b, the distance between the distal bearing portions 42, 52 and the proximal bearing portions 43, 53 can be increased. That is, the configuration adds the flexibility of the arrangement of the bearing portions 43 and 53 with respect to the rotary shafts 25, 35.

(5) Since the bearings 42a, 42b, 43a, 43b, 52a, 52b, 53a, and 53b are fixed at the rotary shafts 25, 35 and the shaft retainers 28, 38, it is possible to prevent the rotary shafts 25, 35 from swaying in the horizontal and vertical directions. It is thus possible to prevent vibrations and noise in the vacuum pump 10 regardless of the rotation speed of the rotary shafts 25, 35.

(6) Since lubricant oil 62 is supplied into the oil recovery passages 48, 58 at the lower side of the distal bearing portions 42, 52, the lubricant oil 62 supplied to the oil recovery passages 48, 58 is hardly influenced by sliding heat of the distal bearing portions 42, 52. It thus becomes easy to control the temperature of the lubricant oil 62 in the oil recovery passages 48, 58.

(7) Since the lubricant oil 62 passes through the synchronous gears 47, 57 on the way of being recovered into the oil storage chamber 61, the synchronous gears 47, 57 can also be lubricated.

[0042] The present invention is not to be limited to the foregoing embodiment, but may be modified as follows within the scope of the invention.

[0043] A gear pump may be adopted for the oil feed pumps 70, 80 instead of a trochoidal pump.

[0044] The lead angle of the teeth of the male rotor and the tooth grooves of the female rotor may be fixed.

[0045] In the above-described embodiment, the respective bearing portions are composed of two angular ball bearings in a state of Duplex Back-to-back. However, these may be composed by a combination thereof in a state of Duplex Face-to-face or by a combination thereof in a state of Duplex Tandem. Further, the respective bearing portions are not limited to angular ball bearings, but may be composed of ordinal deep groove type roller bearings. Still further, the number of the roller bearings is not specifically limited, and the respective bearing portions may be composed of three or more roller bearings. Also, in order to prevent horizontal sway of the rotary shafts with respect to the shaft retainers, it is preferable that angular ball bearings be combined at the backs thereof.

[0046] A thermostat may be used instead of an open/close type solenoid valve 91, or a flow rate control valve which is capable of adjusting the opening degree based on proportional control may be adopted.

[0047] The short conduits 45, 55 may be provided at the upper side of the distal bearing portions 42, 52, and lubricant oil may be supplied from the upper side of the distal bearing portions 42, 52. In this case, the lubricant oil is influenced by the sliding heat of the distal bearing portions 42, 52. Thus, if the lubricant oil is cooled with such influence taken into consideration, the advantages almost equivalent to those of the above-described embodiment are obtained.

[0048] The shaft retainer 28 of the male rotor 21 and the shaft retainer 38 of the female rotor 31 may be composed of completely separate members. In this case, it becomes easy to manufacture the shaft retainers 28, 38.

[0049] The screw-type fluid machine according to the present invention is not limited to a screw-type vacuum pump, but may be applicable to a screw-type compressor.

Claims

1. A screw-type fluid machine, comprising:

a housing;
a pair of screw-type rotors accommodated in the housing and meshed with each other;
a pair of rotary shafts each coaxially coupled to one of the rotors, each rotary shaft having an end portion protruding from the housing;
a pair of cylindrical shaft retainers extending in the housing, each shaft retainer having a first end portion and a second end portion, and having a through hole into which one of the rotary shafts is inserted;
first bearing portions each mounted in the through hole at one of the first end portions;
second bearing portions each mounted in the through hole at one of the second end portions, each pair of the first and second bearing portions rotatably supporting the corresponding rotary shaft with respect to the shaft retainer, and each pair of the first and second bearing portions being fixed in the axial direction with respect to the corresponding rotary shaft and the corresponding shaft retainer;
synchronous gears each provided at the end portion of one of the rotary shafts protruding from the housing;
a gear case in which the synchronous gears are

accommodated, the gear case defining an oil storage space capable of storing lubricant oil;
a cooling portion for cooling the lubricant oil by using a cooling fluid;
a flow rate changing portion for controlling the flow rate of the cooling fluid;
a temperature sensor provided in the oil storage space, which detects the temperature of the lubricant oil; and
a control portion for controlling the flow rate changing portion in accordance with the temperature detected by the temperature sensor so that the temperature of the lubricant oil in the oil storage space is kept constant.

2. The screw-type fluid machine according to claim 1, wherein the first and second bearing portions are each composed of a combination of at least two roller bearings.

3. The screw-type fluid machine according to claim 2, wherein the roller bearings include angular ball bearings.

4. The screw-type fluid machine according to any one of claims 1 to 3, wherein the cooling portion includes a cooling water passage extending in the gear case so as to permit passage of the cooling fluid.

5. The screw-type fluid machine according to any one of claims 1 to 4, further including oil feed portions each driven by one of the rotary shafts so that the shaft retainers and the rotary shafts are cooled by using lubricant oil in the oil storage space.

6. The screw-type fluid machine according to claim 5, wherein a space is provided between the inner circumferential surface of each shaft retainer and the outer circumferential surface of the corresponding rotary shaft, an oil feed passage having an inlet opening to the end portion of the rotary shaft and an outlet communicating with the space is formed at each rotary shaft, wherein the oil feed portion is a pump provided at the end portion of each of the rotary shafts, and the pump supplies lubricant oil existing in the oil storage space to the inlet of the oil feed passage of the corresponding rotary shaft.

Fig.1

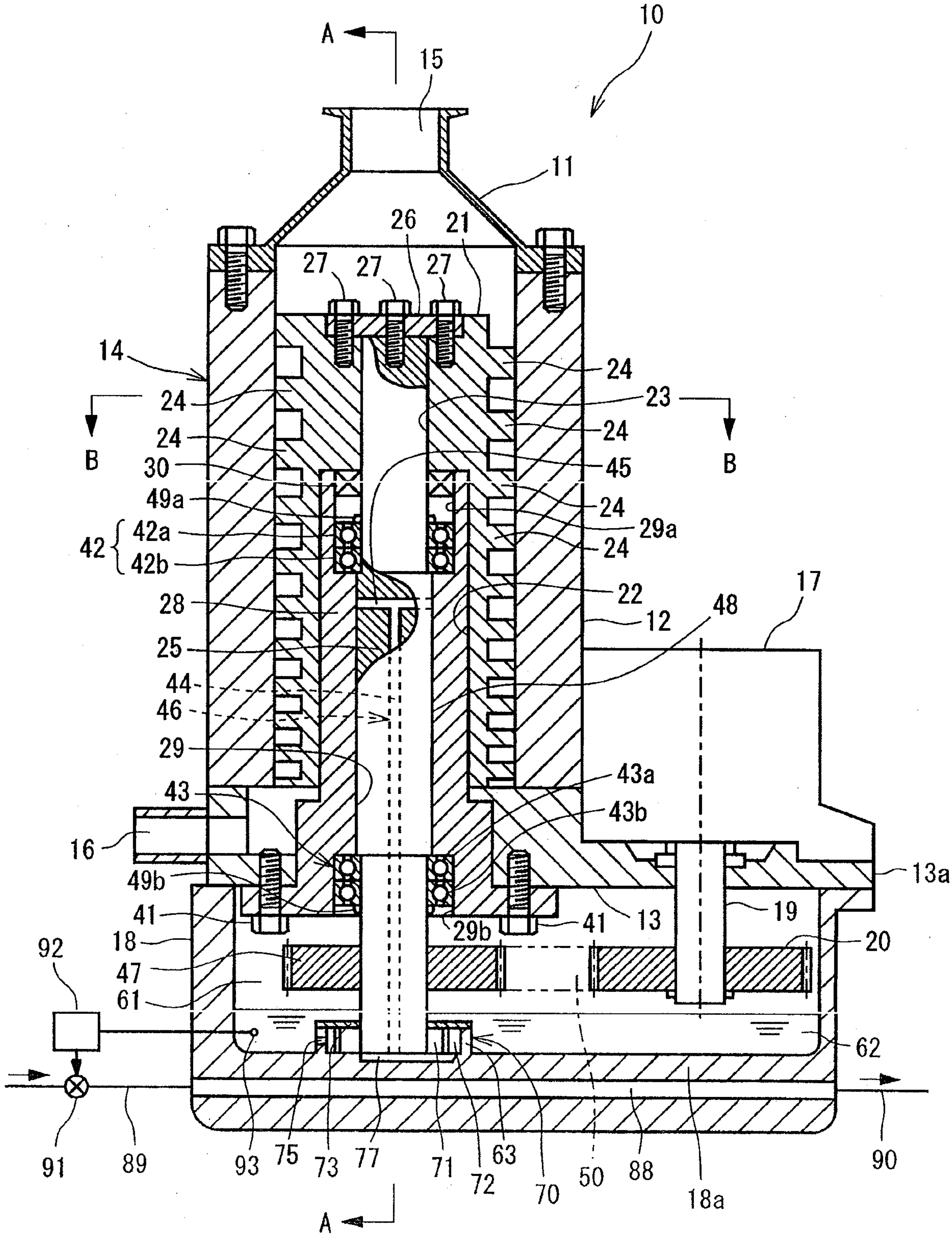

A
15
10
11
26
21
27
27
27
14
24
24
23
B
24
24
B
30
45
49a
24
42
42a
29a
42b
24
22
28
17
12
48
25
44
46
29
43a
43
43b
16
13a
49b
19
41
41
13
18
29b
20
92
47
61
62
91
89
93
75
73
77
71
72
63
70
50
88
18a
90
A

Fig.2

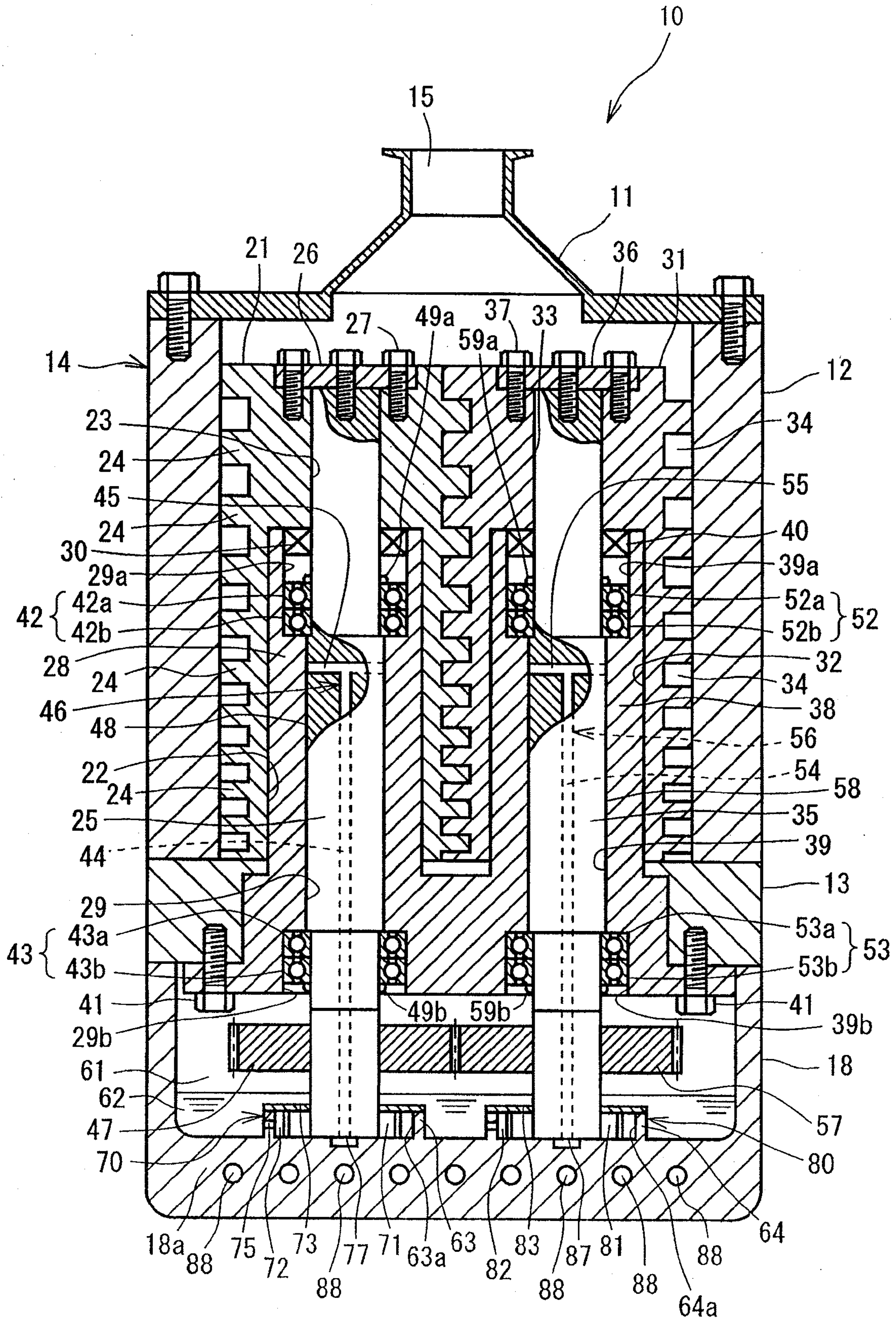

10
15
11
21
26
36
31
27
49a
37
33
59a
14
12
23
24
34
45
55
24
40
30
29a
39a
42
42a
42b
52a
52b
52
28
24
32
34
46
38
48
56
22
24
54
58
25
35
44
39
13
29
43
43a
43b
53a
53b
53
41
41
29b
49b
59b
39b
61
18
62
47
57
70
80
18a
88
75
72
73
88
77
71
63a
63
82
83
88
87
81
88
64a
88
64

Fig.3

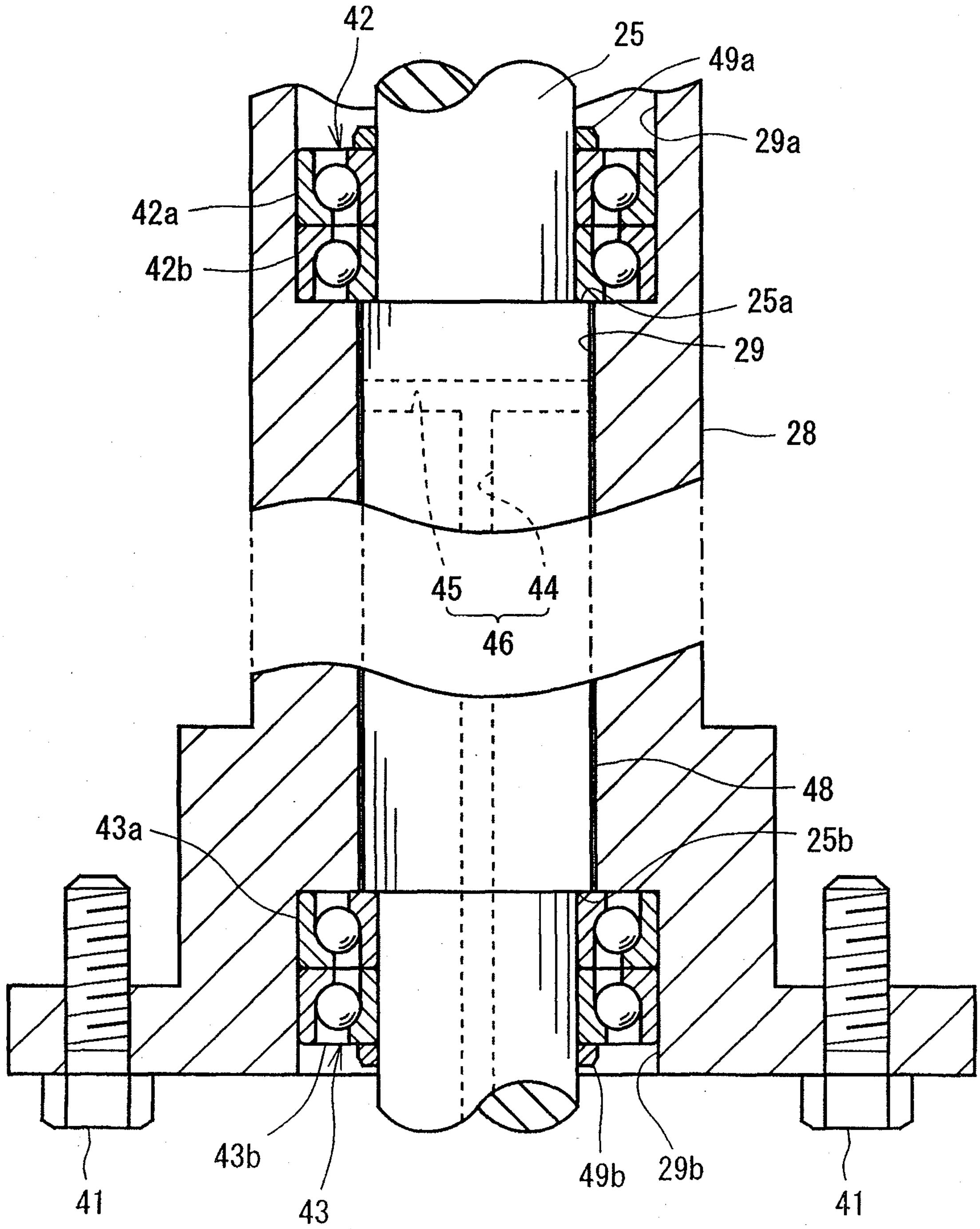

42
25
49a
29a
42a
42b
25a
29
28
45
44
46
48
43a
25b
43b
43
49b
29b
41
41

Fig.4

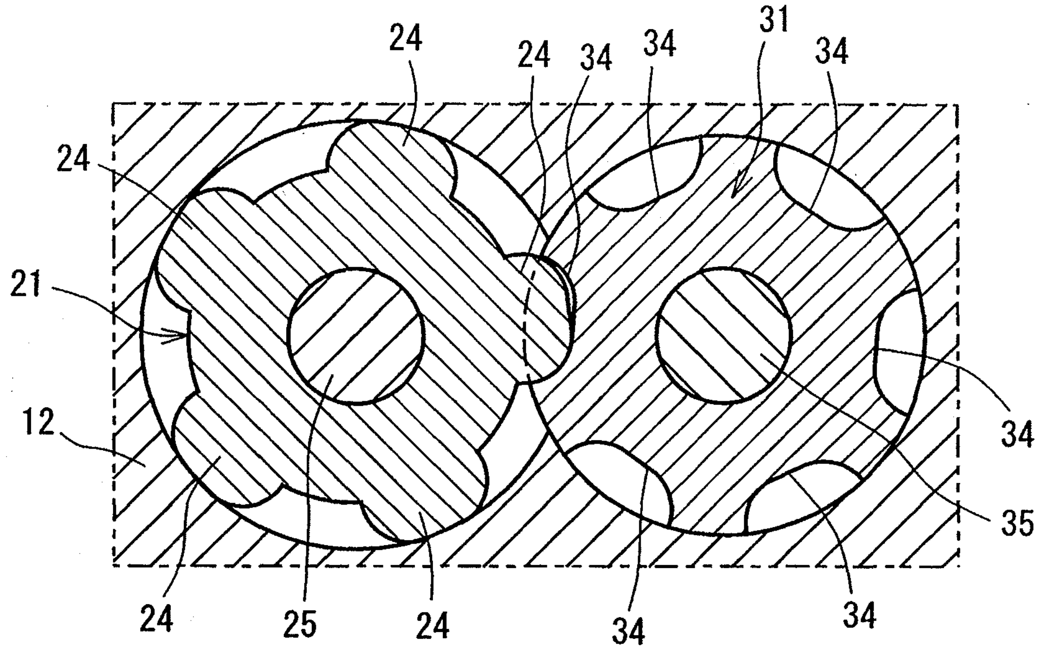
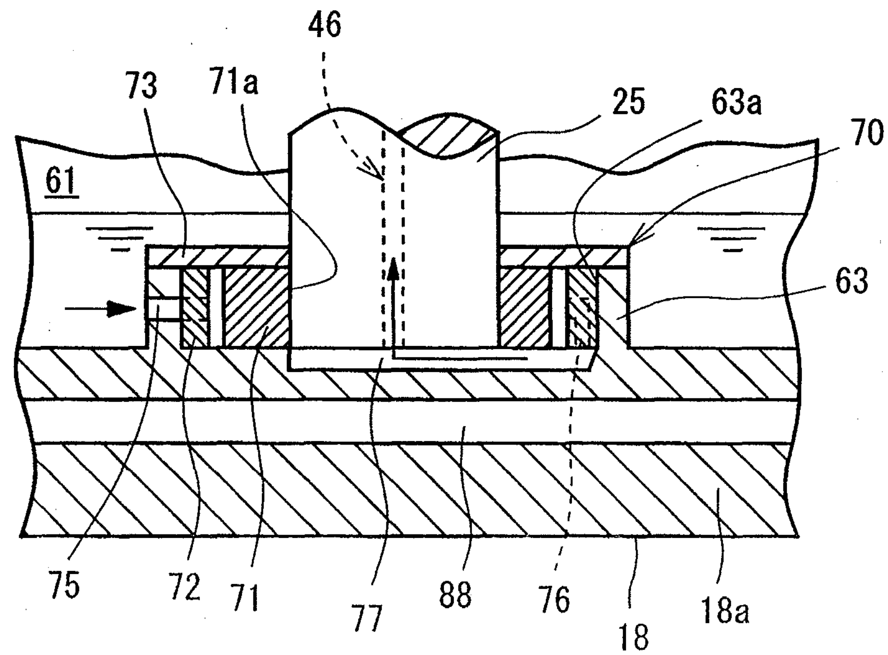

24
24
34
34
31
34
24
21
12
34
35
24
25
24
34
34

Fig.5


46
73
71a
25
63a
70
61
63
75
72
71
77
88
76
18
18a

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/325864

A. CLASSIFICATION OF SUBJECT MATTER
F04C18/16(2006.01)i, *F04C25/02*(2006.01)i, *F04C29/02*(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)
F04C18/16, F04C25/02, F04C29/02

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	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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.
Y	JP 4-314991 A (Hitachi, Ltd.), 06 November, 1992 (06.11.92), Par. Nos. [0011] to [0016]; Figs. 1 to 6 (Family: none)	1-6
Y	JP 2005-248741 A (Tadahiro OMI), 15 September, 2005 (15.09.05), Par. Nos. [0026] to [0031]; Figs. 1, 2 & WO 2005/085643 A1	1-6
Y	JP 10-141260 A (Diavac Ltd.), 26 May, 1998 (26.05.98), Par. No. [0031]; Fig. 2 (Family: none)	1-6

☒ 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 22 January, 2007 (22.01.07)	Date of mailing of the international search report 30 January, 2007 (30.01.07)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/325864

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 11-182478 A (Kobe Steel, Ltd.), 06 July, 1999 (06.07.99), Par. No. [0003]; Fig. 2 (Family: none)	1-6
A	JP 11-508015 A (SIHI Industry Consult GmbH), 13 July, 1999 (13.07.99), Page 9, line 14 to page 10, line 7; Fig. 1 & US 5924855 A & EP 0834018 B1 & WO 1997/001038 A1 & DE 19522557 A1	1-6
A	JP 2000-64975 A (The BOC Group plc.), 03 March, 2000 (03.03.00), Par. Nos. [0016] to [0019]; Fig. 1 & US 6200116 B1 & US 6217305 B1 & EP 0965756 A2 & EP 0965757 A2 & EP 0965758 A2 & JP 2000-64976 A & JP 2000-73976 A & DE 69928172 T2 & DE 69929749 T2	1-6
A	WO 2004/074690 A1 (RIETSCHLE THOMAS GMBH + CO. KG), 02 September, 2004 (02.09.04), Description, page 6, line 12 to page 7, line 18; Fig. 1 & US 2006/0222553 A1 & JP 2006-518827 A & DE 20302989 U1 & CN 1768206 A	1-6

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 4314991 A **[0006]**