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

(11) EP 1 318 308 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.06.2003 Bulletin 2003/24

(51) Int Cl.⁷: **F04D 19/04**

(21) Application number: **02258145.8**

(22) Date of filing: **27.11.2002**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **04.12.2001 JP 2001370627**

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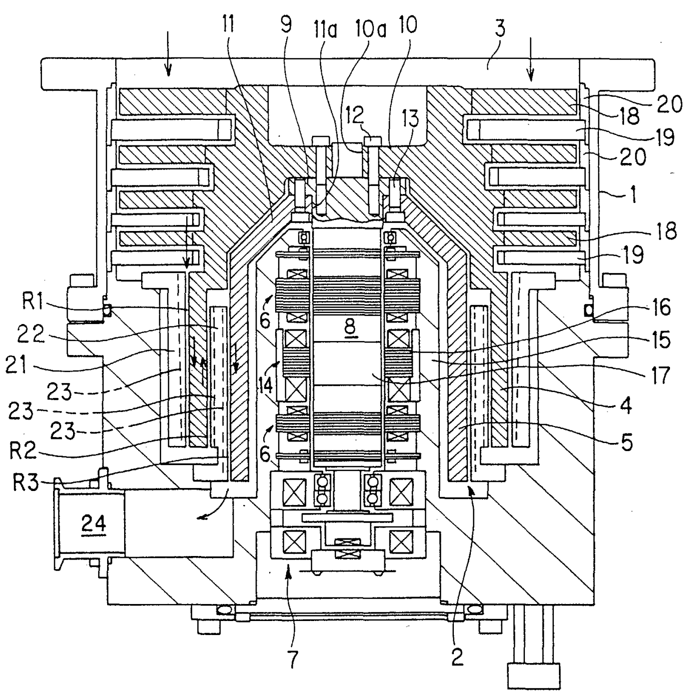
(54) Vacuum pump

(57) A multiple cylinder (2) having a plurality of cylinders (4, 5) arranged concentrically and a rotor shaft (8) rotatably disposed on the center axis of the multiple cylinder are provided in a pump casing (1). Each of the cylinders that constitute the multiple cylinder has a mounting portion (10, 11), through which the cylinders are integrally fixed to the rotor shaft.

FIG. 1



EP 1 318 308 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a vacuum pump used for a semiconductor manufacturing apparatus, an electron microscope, a surface analysis apparatus, a mass spectrograph, a particle accelerator, an atomic fusion experimental apparatus and so on.

2. Description of the Related Art

[0002] Pumps (hereinafter, referred to as compound-type vacuum pumps) that combine a turbo-molecular pump and a thread-groove pump are well known as this type of vacuum pump. Such compound-type vacuum pumps employ a structure in which a series of exhaust passages R1, R2, and R3 of the thread-groove pump are turned back in order to increase the pump compression ratio and miniaturize the whole pump, as shown in Figs. 6 and 7.

[0003] In order to obtain a turn-back structure of the exhaust passages R1, R2, and R3 of the thread-groove pump, the compound-type vacuum pumps shown in Figs. 6 and 7 have a structure in which a substantially lower half of a rotor (rotation body) 70 which functions as a thread-groove pump has a multiple cylinder 2 composed of two cylinders 4 and 5, and screw pump stators 21 and 22 with a thread groove are disposed on the outside of the outer cylinder 4 and between the outer and inner cylinders 4 and 5, respectively. In the compound-type vacuum pump shown in Figs. 6 and 7, since the upper half of the rotor 70 works as a turbo-molecular pump, a plurality of rotor blades 18 is integrally formed on the outer peripheral surface of the upper part of the rotor 70.

[0004] Here, both the rotors 70 of the compound-type vacuum pumps shown in Figs. 6 and 7 have a structure of the multiple cylinder 2 and the rotor blades 18. However, the rotor 70 of the compound-type vacuum pump shown in Fig. 6 is formed such that the multiple cylinder 2 and the rotor blades 18 are cut out from one rotor forming material. The rotor 70 of the compound-type vacuum pump shown in Fig. 7 is formed such that two cylinders 4 and 5 are joined later to the vicinity of the lowermost rotor blade 18 by adhesive bonding or shrink fitting.

[0005] However, for manufacturing the rotor 70 having the structure of the multiple cylinder 2 and the rotor blades 18, by the method of cutting out the multiple cylinder 2 and the rotor blades 18 from one rotor forming material as described above, the cutting shape is too difficult to form the rotor 70 because of complication of its shape, thus causing an increase in the cost of the whole pump.

[0006] By the method of joining the two cylinders 4 and 5 to the vicinity of the lowermost rotor blade 18 later by adhesive bonding or shrink fitting, as described above, it is difficult to ensure the durability of the joint section, requiring high processing accuracy, thus leading to a higher cost of the whole pump. Also, the periphery of the joint sections of the cylinders 4 and 5, that is, the vicinity of the lowermost rotor blade 18 has a large displacement especially by a centrifugal force during the operation of the pump; moreover, the vicinity of the lowermost rotor blade 18 has a displacement by thermal expansion due to the heat of compression that generates during the operation of the pump, so that the areas for mounting the cylinders 4 and 5 change to cause an unstable mounting state of the cylinders 4 and 5. Accordingly, the center of rotation of the cylinders 4 and 5 tends to deviate from the center axis of rotation of a rotor shaft 8 and the rotor blades 18, in other words, off-core of the rotor blades 18 is likely to occur. Such off-core of the rotor blades 18 increases an imbalance of the rotor 70 to cause vibration and a decrease in the life and damage to a shaft bearing for supporting the rotor 70.

[0007] Particularly, when the cylinders 4 and 5 and the rotor blades 18 are made of different types of materials, the phase difference due to the difference in coefficient of thermal expansion, modulus of elasticity, and Poisson's ratio between the different types of materials causes a further unstable mounting state of the cylinders 4 and 5, particularly causes imbalance of the rotor 70.

SUMMARY OF THE INVENTION

[0008] The present invention has been made to solve the above problems and the object thereof is to prevent imbalance of a rotation body during the operation of the pump and to provide a highly-reliable low-cost vacuum pump capable of obtaining a stable operation for a long period of time.

[0009] In order to achieve the above object, the present invention comprises: a multiple cylinder having a plurality of cylinders arranged concentrically; a rotor shaft rotatably disposed on the center axis of said multiple cylinder; and a screw pump stator having an exhaust passage of a thread-groove pump between it and each of said cylinders; wherein each of the cylinders constituting the multiple cylinder has a mounting portion, through which each cylinder is integrally mounted to the rotor shaft.

[0010] In the present invention, preferably, the rotor shaft has a collar on the outer peripheral surface; each of the cylinders constituting the multiple cylinder has a mounting portion to the collar; and the mounting portions of the cylinders and the collar of the rotor shaft are integrally joined.

[0011] In the above arrangement having the collar on the outer peripheral surface of the rotor shaft, preferably, the mounting portion of the outer cylinder is fixed to the surface of the collar and the mounting portion of the inner cylinder is fixed to the back of the collar.

[0012] In the above arrangement having the collar on the outer peripheral surface of the rotor shaft, preferably, the mounting portion of the inner cylinder is disposed on the surface of the collar, on which the mounting portion of the outer cylinder is disposed; and both the mounting portions of the inner and outer cylinders are fastened to the collar with bolts passing therethrough.

[0013] In the above arrangement having the collar on the outer peripheral surface of the rotor shaft, preferably, the collar has a shoulder; wherein the mounting portion of the outer cylinder is fastened to the upper step of the shoulder with bolts; and the mounting portion of the inner cylinder is fastened to the lower step of the shoulder with other bolts.

[0014] In the present invention, preferably, the outer periphery of the end of the rotor shaft is tapered from the end face of the rotor shaft to a mounting position for the outer cylinder; and a tapered hole to be fitted to the tapered portion of the rotor shaft is opened in the mounting portion of the outer cylinder; wherein the rotor shaft and the outer cylinder are integrally joined by a counter joining structure in which the tapered hole and the tapered section are fitted to each other.

[0015] In the above arrangement in which the outer cylinder is fixed to the rotor shaft, preferably, a push ring which is in contact with the periphery of the tapered hole of the mounting portion of the outer cylinder is disposed at the end face of the rotor shaft and wherein the outer cylinder is fastened to the rotor shaft with a bolt screwed into the end of the rotor shaft through a bolt insertion hole of the push ring.

[0016] In the present invention, preferably, the outer periphery of the end of the rotor shaft is tapered from the end face of the rotor shaft to a mounting position for the inner cylinder through the mounting position for the outer cylinder; and a tapered hole to be fitted to the tapered portion of the rotor shaft is opened in each of the mounting portion of the outer cylinder and the mounting portion of the inner cylinder; wherein the rotor shaft, the outer cylinder, and the inner cylinder are integrally joined by a counter joining structure in which the tapered hole and the tapered section are fitted to each other.

[0017] In the above arrangement in which the inner cylinder is fixed to the rotor shaft, preferably, a screw part is provided at the periphery of the end of the rotor shaft and at a position slightly higher than the mounting position for the inner cylinder; and the inner cylinder is fastened to the rotor shaft with a nut on the screw part tightened from above the mounting portion of the inner cylinder.

[0018] In the present invention, preferably, a plurality of rotor blades and stator blades are alternately provided on the outer periphery of the outer cylinder of the cylinders; wherein the rotor blades are integrated with the outer peripheral surface of the outer cylinder; and the stator blades are fixed to the inner surface of a pump casing.

[0019] In the present invention, preferably, the multiple cylinder includes a pair of inner and outer cylinders arranged concentrically; the screw pump stator includes a first screw-pump stator arranged at a position facing the outer peripheral surface of the outer cylinder and a second screw-pump stator arranged between the outer cylinder and the inner cylinder; the exhaust passage of the thread-groove pump includes a first gas-exhaust passage provided between the first screw-pump stator and the outer cylinder, a second gas-exhaust passage provided between the outer cylinder and the second screw-pump stator, and a third gas-exhaust passage provided between the second screw-pump stator and the inner cylinder; wherein the first gas-exhaust passage and the second gas-exhaust passage communicate under the outer cylinder; and the second gas exhaust passage and the third gas exhaust passage communicate above the second screw-pump stator.

BRIEF DESCRIPTION OF THE DRABLADES

[0020] Fig. 1 is a sectional view of an embodiment of a vacuum pump according to the present invention;

[0021] Fig. 2 is a sectional view of a second embodiment of a vacuum pump according to the present invention;

[0022] Fig. 3 is a sectional view of a third embodiment of a vacuum pump according to the present invention;

[0023] Fig. 4 is a sectional view of a forth embodiment of a vacuum pump according to the present invention;

[0024] Fig. 5 is a sectional view of a fifth embodiment of a vacuum pump according to the present invention;

[0025] Fig. 6 is a sectional view of a conventional vacuum pump; and

[0026] Fig. 7 is a sectional view of another conventional vacuum pump.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Referring to Figs. 1 to 5, embodiments of a compound-type vacuum pump incorporating a vacuum pump according to the present invention will be described hereinbelow.

[0028] A compound-type vacuum pump shown in Fig. 1 includes a multiple cylinder 2 as a rotation body in a cylindrical pump casing 1. The multiple cylinder 2 is arranged so that the upper end thereof faces a gas suction port 3 at the upper part of the pump casing 1.

[0029] In this embodiment, the multiple cylinder 2 has a double-cylindrical structure in which two cylinders 4 and 5 are arranged concentrically. A rotor shaft 8 is provided so as to be rotatably erected on the center axis of the multiple cylinder 2 having the inner and outer pair of cylinders 4 and 5 through a radial bearing 6 and a thrust bearing 7.

[0030] The rotor shaft 8 has a collar 9 on the upper peripheral surface integrally. On the other hand, the two cylinders 4 and 5 constituting the multiple cylinder 2 have mounting portions 10 and 11 to the collar 9 at the respective upper parts thereof. By integrally joining the respective mounting portions 10 and 11 of the cylinders 4 and 5 and the collar 9 of the rotor shaft 8, the two cylinders 4 and 5 are integrally secured to the rotor shaft 8.

[0031] Several types of joining structures of the cylinders 4 and 5 and the rotor shaft 8 may be provided; however, this embodiment employs, as a joining structure, a structure in which mounting holes 10a and 11a are opened in respective mounting portions 10 and 11 of the inner and outer cylinders 4 and 5, through which the respective mounting portions 10 and 11 of the inner and outer cylinders 4 and 5 are mounted to the rotor shaft 8, and in which the mounting portion 10 of the outer cylinder 4 is fastened to the surface of the collar 9 with bolts 12, and the mounting portion 11 of the inner cylinder 5 is fastened to the back of the collar 9 with the other bolts 13.

[0032] In this embodiment, the radial bearing 6 and the thrust bearing 7 that support the rotor shaft 8 are magnetic bearings, with which the rotor shaft 8 is supported in the radial direction and the thrust direction.

[0033] The rotor shaft 8 is driven to rotate by a drive motor 14. The drive motor 14 of this embodiment has a structure in which a motor stator 16 is mounted to a motor stator column 15 provided inside the multiple cylinder 2 and a motor rotor 17 is mounted on the peripheral surface of the rotor shaft 8 which faces the motor stator 16.

[0034] In the compound-type vacuum pump shown in Fig. 1, the substantially upper half of the multiple cylinder 2 functions as a turbo-molecular pump and the substantially lower half of the multiple cylinder 2 functions as a thread-groove pump.

[0035] First, the structure of the substantially upper half of the multiple cylinder 2 that functions as a turbo-molecular pump will be described.

[0036] A plurality of worked rotor blades 18 and stator blades 19 are provided on the upper outer periphery of the multiple cylinder 2, that is, on the upper outer periphery of the outer cylinder 4 of the inner and outer pair of cylinders 4 and 5. The rotor blades 18 and the stator blades 19 are alternately arranged along the center axis of rotation of the multiple cylinder 2.

[0037] More specifically, the multiple cylinder 2 has, at the upper outer periphery, the stator blades 19 between the upper and lower rotor blades 18, or has the rotor blades 18 between the upper and lower stator blades 19.

[0038] The rotor blades 18 are integrated with the upper outer peripheral surface of the outer cylinder 4 by integral processing with the outer cylinder 4, and can be rotated integrally with the inner and outer cylinders 4 and 5. The stator blades 19 are fixed to the inner surface of the pump casing 1 through spacers 20.

[0039] In the compound-type vacuum pump of this embodiment, when the multiple cylinder 2 is rotated with the rotor shaft 8, the gas molecules are exhausted from the gas suction port 3 at the upper part of the pump casing 1 toward the lowermost rotor blade 18 and stator blade 19 at the substantially upper half of the multiple cylinder 2 by the interaction of the rotor blades 18 and the stator blades 19. The exhaust gas is sequentially fed to the next stage, that is, to the substantially lower half of the multiple cylinder 2 functioning as a thread-groove pump.

[0040] Next, in the multiple vacuum cylinder shown in Fig. 1, the structure of the substantially lower half of the multiple cylinder 2 functioning as the thread-groove pump will be described.

[0041] While the multiple cylinder 2 is constituted by a pair of inner and outer cylinders 4 and 5, as described above, a first screw-pump stator 21 is disposed at a position which faces the outer peripheral surface of the outer cylinder 4, and a second screw-pump stator 22 is disposed between the outer cylinder 4 and the inner cylinder 5. Both the first and second screw-pump stators 21 and 22 are shaped like a cylinder similar to the cylinders 4 and 5 constituting the multiple cylinder 2.

[0042] The first screw-pump stator 21 has a thread groove 23 at the inner surface, that is, a surface facing the outer peripheral surface of the outer cylinder 4. The second screw-pump stator 22 has thread grooves 23 at the inner and outer surfaces, that is, a surface facing the inner peripheral surface of the outer cylinder 4 and a surface facing the outer peripheral surface of the inner cylinder 5.

[0043] A first gas-exhaust passage R1 is provided between the first screw-pump stator 21 and the outer cylinder 4; a second gas-exhaust passage R2 is provided between the outer cylinder 4 and the second screw-pump stator 22; and a third gas-exhaust passage R3 is provided between the second screw-pump stator 22 and the inner cylinder 5. The first gas-exhaust passage R1 and the second gas-exhaust passage R2 communicate with each other at the lower end of the outer cylinder 4; and the second gas-exhaust passage R2 and the third gas-exhaust passage R3 are communicated with each other at the upper end of the second screw-pump stator 22.

[0044] In the compound-type vacuum pump of this embodiment, when the multiple cylinder 2 is rotated with the rotor shaft 8, the substantially lower half of the multiple cylinder 2 functions as a thread-groove pump. More specifically, a gas is exhausted by the relative motion between the two cylinders 4 and 5 and the thread grooves 23 of the screw pump stators 21 and 22. The flow of the gas to be exhausted will be described as follow:

[0045] The exhaust gas first flows into the first gas-exhaust passage R1 from the lowermost rotor blade 18 and stator blade 19 and flows therein downwardly in the drawing. The downward flowing gas is 180° reversed at the lower end of the outer cylinder 4, and then flows into the second gas-exhaust passage R2, and flows therein upwardly in the drawing. Subsequently, the upward flowing gas is 180° reversed at the upper end of the second screw-pump stator 22, then flows into the third gas-exhaust passage R3, and flows therein downwardly in the drawing, and finally flows from the lower end of the inner cylinder 5 to a gas exhaust port 24 for discharge.

[0046] In the compound-type vacuum pump of this embodiment, while the substantially lower half of the multiple cylinder 2 functions as a thread-groove pump, as described above, the series of gas exhaust passages (R1, R2, and R3) of this thread-groove pump turn over at the upper and lower points, that is, at the lower end of the outer cylinder 4 and the upper end of the second screw-pump stator 22.

[0047] The gas suction port 3 at the upper part of the pump casing 1 connects to a high vacuum vessel including a process chamber of a semiconductor manufacturing apparatus, and the gas exhaust port 24 at the lower part of the pump casing 1 is set so as to communicate with an auxiliary pump (not shown). Therefore, the compound-type vacuum pump of this embodiment is constructed such that the turbo-molecular-pump functioning section that performs evacuation by the interaction between the rotor blades 18 and the stator blades 19 is positioned on a high vacuum side, and the thread-groove-pump functioning section that performs evacuation by the interaction between the inner and outer cylinders 4 and 5 and the thread grooves 23 is positioned on the auxiliary pump side (not shown).

[0048] Referring to Fig. 1, the use example and operation of the compound-type vacuum pump of this embodiment, constructed as described above, will be described. The arrows in the drawing indicate the flow direction of the exhaust gas in the pump.

[0049] The compound-type vacuum pump in this drawing can be used, for example, as a means for evacuating the inside of a process chamber of the semiconductor manufacturing apparatus, in which the gas suction port 3 of the pump casing 1 connects to the process chamber.

[0050] In the compound-type vacuum pump connected as described above, when the auxiliary pump (not shown) connected to the gas exhaust port 24 is activated to evacuate the process chamber to a predetermined vacuum level and an operation start switch is then turned on, the drive motor 14 is activated to rotate the multiple cylinder 2 and the rotor blades 18 integrally with the rotor shaft 8.

[0051] In this case, in the evacuating operation for the gas molecules in the turbo-molecular-pump functioning section, the uppermost rotor blade 18, which is rotating at a high speed, applies a momentum in the direction of the gas exhaust port 24 to gas molecules injected through the gas suction port 3, and the gas molecules having the downward momentum are carried to the stator blades 19 and are fed to the next lower rotor blade 18. By repeating the application of momentum, the gas molecules are carried from the gas suction port 3 toward the lowermost stator blade 19 for discharge.

[0052] The gas molecules that have reached the lowermost stator blade 19, as described above, are carried toward the gas discharge port 24 through the gas exhaust passages (R1, R2, and R3), where the gas molecules are compressed from a intermediate flow to a viscous flow by the relative movement between the cylinders 4 and 5 and the thread grooves 23. The compressed gas is discharged from the gas exhaust port 24 to the exterior of the pump through the auxiliary pump (not shown).

[0053] The compound-type vacuum pump of this embodiment employs a structure in which the two cylinders 4 and 5 constituting the multiple cylinder 2 have the mounting portions 10 and 11, respectively, with which the cylinders 4 and 5 are integrally fixed to the rotor shaft 8. Therefore, when manufacturing the rotation body (rotor) of the multiple cylinder 2 constituted by the outer cylinder 4 with the rotor blades 18 and the inner cylinder 5 without the rotor blades 18, there is no need to cut out the multiple-cylindrical structure portion and the rotor blades 18 from one rotor forming material, but after the outer cylinder 4 with the rotor blades 18 and the inner cylinder 5 without the rotor blades 18 have been formed, the outer and inner cylinders 4 and 5 may be combined concentrically and fixed to the rotor shaft 8. Therefore, the processing is simplified as compared with the conventional art, thus reducing the cost of the whole pump.

[0054] During the operation of the pump, the displacement of the rotor shaft 8 due to the heat of compression of the pump is smaller than that of the rotor blades 18 and so on. Since this embodiment employs a structure in which the cylinders 4 and 5 are mounted to the rotor shaft 8 having a small displacement, the load applied to the mounting portions of the cylinders 4 and 5 is small, so that the cylinders 4 and 5 can be maintained in stable positions for a long period of time, thus preventing problems due to an unstable mounting state, for example, deviation of the rotational center axes of the rotor blades 18 integrated with the outer cylinder 4 from the geometrical central axes of the rotor shaft 8 and the rotor blades 18, so-called off-core of the rotor blades 18, and resultant imbalance of the multiple cylinder 2, providing a high-reliable vacuum pump capable of obtaining a stable operation for a long period of time.

[0055] The joining structure of the cylinders 4 and 5 and the rotor shaft 8 may be other structures shown in Figs. 2 to 5 in addition to that of the above-described embodiment shown in Fig. 1, which can also provide similar advantages.

[0056] In the joining structure of Fig. 2, the mounting portion 11 of the inner cylinder 5 is arranged on the surface of the collar 9, on which the mounting portion 10 of the outer cylinder 4 is arranged, and the mounting portions 10 and 11 of the outer and inner cylinders 4 and 5 are fastened to the collar 9 of the rotor shaft 8 with bolts 12 that pass through the mounting portions 10 and 11.

[0057] In the joining structure of Fig. 3, the collar 9 has a shoulder 25, to an upper step 25a of which the mounting portion 10 of the outer cylinder 4 is fastened with the bolts 12, and to a lower step 25b of which the mounting portion 11 of the inner cylinder 5 is fastened with the other bolts 13.

[0058] The joining structure of Fig. 4 is a center lock structure in which the mounting portion 10 of the outer cylinder 4 is fastened to the end center of the rotor shaft 8 with the bolt 12. In the center lock structure, the outer periphery of the end of the rotor shaft 8 is tapered from the end face to the position of mounting the outer cylinder 4; a tapered hole 27 to be fitted on a tapered portion 26 of the rotor shaft 8 is opened in the mounting portion 10 of the outer cylinder 4; and the rotor shaft 8 and the outer cylinder 4 are joined in one by a counter lock structure in which the tapered hole 27 and the tapered portion 26 are fitted to each other.

[0059] In the joining structure of Fig. 4, for fixing the outer cylinder 4 to the rotor shaft 8, the mounting portion 10 of the outer cylinder 4 is mounted to the outer-cylinder-4 mounting position of the rotor shaft 8 through the tapered hole 27 of the mounting portion 10 of the outer cylinder 4, then the push ring 28 that is in contact with the periphery of the tapered hole 27 of the mounting portion 10 is arranged at the end face of the rotor shaft 8, and the bolt 12 may be screwed into the end of the rotor shaft 8 through a bolt insertion hole of the push ring 28. Thus, the driving torque is applied to the mounting portion 10 of the outer cylinder 4 through the push ring 28, and a wedge effect is produced between the tapered portion 26 and the tapered hole 27, thereby firmly fastening the outer cylinder 4 to the rotor shaft 8.

[0060] In the joining structure of Fig. 4, the inner cylinder 5 does not employ the center lock structure as in the outer cylinder 4, but adopts a structure in which the mounting portion 11 of the cylinder 5 is fastened to the collar 9 on the peripheral surface of the rotor shaft 8 with the bolts 13.

[0061] In the joining structure of Fig. 5, both the inner and outer cylinders employ the center lock structure. In this structure, the outer periphery of the end of the rotor shaft 8 is tapered between the end face thereof to the mounting position for the inner cylinder 5 through the mounting position for the outer cylinder 4; the tapered hole 27 to be fitted on the tapered portion 26 of the rotor shaft 8 is opened in the mounting portion 11 of the inner cylinder 5; and the rotor shaft 8 and the inner cylinder 5 are joined in one by the counter lock structure in which the tapered hole 27 and the tapered portion 26 are fitted to each other. The outer periphery of the end of the rotor shaft 8 has a screw part 30 at a position slightly higher than the mounting position for the inner cylinder 5, onto which a nut 31 is fitted.

[0062] In the joining structure of Fig. 5, for fixing the inner cylinder 5 to the rotor shaft 8, the mounting portion 11 of the inner cylinder 5 is mounted to the inner-cylinder-5 mounting position of the rotor shaft 8 through the tapered hole 27 of the mounting portion 10 of the inner cylinder 5, then the nut 31 on the screw part 30 may be fastened from above the mounting portion 11. Thus, the fastening force of the nut 31 causes a wedge effect between the tapered portion 26 and the tapered hole 27, thereby firmly fastening the inner cylinder 5 to the rotor shaft 8. Since the center lock structure of the outer cylinder 4 is similar to that of the example shown in Fig. 4, a specific description thereof will be omitted.

[0063] In the above embodiments, while examples of forming the thread grooves 23 in the screw pump stators 21 and 22 were described, alternatively, the thread grooves 23 may be formed in the cylinders 4 and 5.

[0064] In the above embodiments, while examples of employing the multiple cylinder 2 composed of the two cylinders 4 and 5 were described, the present invention can be applied to a multiple cylinder having two or more cylinders arranged concentrically, and the number of the cylinders constituting the multiple cylinder is not limited to two.

[0065] In the above embodiments, examples of a so-called compound-type vacuum pump in which the upper half of the multiple cylinder 2 functions as a turbo-molecular pump and the lower half functions as a thread-groove pump were described; however, the present invention can also be applied to a vacuum pump having a structure in which the whole multiple cylinder 2 functions as a turbo-molecular pump, in other words, the rotor blades 18 are provided over the whole peripheral surface of the outer cylinder 4, that is a so-called blade vacuum pump, and to a vacuum pump having only a function of a thread-groove pump without the rotor blades 18 over the peripheral surface of the outer cylinder 4.

[0066] As described above, according to the present invention, each of a plurality of cylinders that constitute a multiple cylinder has a mounting portion, through which the cylinders are integrally fixed to a rotor shaft. Therefore, for example, when a rotation body (rotor) of a multiple cylinder constituted by an outer cylinder with rotor blades and an inner cylinder without the rotor blades is manufactured, there is no need to cut out the multiple-cylindrical structure portion and the rotor blades from one rotor forming material; but all that is needed is to form the outer cylinder with the rotor blades and the inner cylinder without the rotor blades separately, then combine the outer and inner cylinders concentrically, and fix it to the rotor shaft. Therefore, the processing is simplified as compared with the conventional art, thus reducing the cost of the whole pump.

[0067] During the operation of the pump, the displacement of the rotor shaft due to the heat of compression of the pump is smaller than those of the rotor blades and so on. According to the present invention, since the cylinders are fixed to the rotor shaft having a small displacement, the load applied to the fixing sections of the cylinders is small, so that the cylinders can be maintained in stable positions for a long period of time, thus preventing problems due to an unstable mounting state, for example, the deviation of the center axes of rotation of the rotor blades 18, which are provided at the outer cylinder constituting the multiple cylinder, from the geometrical central axes of the rotor shaft and the rotor blades, so-called off-core of the rotor blades, and resultant imbalance of the multiple cylinder, thus providing a high-reliable vacuum pump capable of obtaining a stable operation for a long period of time.

Claims

1. A vacuum pump comprising:

a multiple cylinder (2) having a plurality of cylinders (4, 5) arranged concentrically;
a rotor shaft (8) rotatably disposed on the center axis of said multiple cylinder; and
a screw pump stator (21, 22) having an exhaust passage of a thread-groove pump between said screw pump stator and each of said cylinders;

wherein each of the cylinders constituting said multiple cylinder has a mounting portion (10, 11), through which said each cylinder is integrally mounted to the rotor shaft.

2. A vacuum pump according to Claim 1, wherein said rotor shaft has a collar (9) on the outer peripheral surface; each of the cylinders constituting said multiple cylinder has a mounting portion to said collar; and the mounting portion of said cylinder and the collar of said rotor shaft are integrally joined.

3. A vacuum pump according to Claim 2, wherein the mounting portion of said outer cylinder is fixed to the surface of said collar and the mounting portion of said inner cylinder is fixed to the back of said collar.

4. A vacuum pump according to Claim 2, wherein the mounting portion of said inner cylinder is disposed on the surface of said collar, on which the mounting portion of said outer cylinder is disposed and both the mounting portions of the inner and outer cylinders are fastened to said collar with bolts (12, 13) passing therethrough.

5. A vacuum pump according to Claim 2, wherein said collar has a shoulder (25); and wherein the mounting portion of the outer cylinder is fastened to the upper step (25a) of the shoulder with bolts and the mounting portion of the inner cylinder is fastened to the lower step (25b) of the shoulder with other bolts.

6. A vacuum pump according to Claim 1, wherein the outer periphery of the end of said rotor shaft is tapered from the end face of the rotor shaft to a mounting position for said outer cylinder and a tapered hole (27) to be fitted to the tapered portion (26) of the rotor shaft is opened in the mounting portion of said outer cylinder and wherein said rotor shaft and said outer cylinder are integrally joined by a counter joining structure in which said tapered hole and said tapered section are fitted to each other.

7. A vacuum pump according to Claim 6, wherein a push ring (28) which is in contact with the periphery of the tapered hole of the mounting portion of said outer cylinder is disposed at the end face of said rotor shaft, said outer cylinder being fastened to said rotor shaft with a bolt. screwed into the end of the rotor shaft through a bolt insertion hole of the push ring.

8. A vacuum pump according to Claim 1, wherein the outer periphery of the end of said rotor shaft is tapered from the end face of the rotor shaft to a mounting position for said inner cylinder through the mounting position for said outer cylinder and a tapered hole to be fitted to the tapered portion of the rotor shaft is opened in each of the mounting portion of said outer cylinder and the mounting portion of said inner cylinder and wherein said rotor shaft, said outer cylinder, and said inner cylinder are integrally joined by a counter joining structure in which said tapered hole and said tapered section are fitted to each other.

9. A vacuum pump according to Claim 8, wherein a screw part (30) is provided at the periphery of the end of said rotor shaft and at a position slightly higher than the mounting position for said inner cylinder and said inner cylinder is fastened to said rotor shaft with a nut (31) on said screw part tightened from above the mounting portion of said inner cylinder.

10. A vacuum pump according to Claim 1, wherein a plurality of rotor blades (18) and stator blades (19) are alternately provided on the outer periphery of the outer cylinder of said cylinders, said rotor blades being integrated with the outer peripheral surface of the outer cylinder and said stator blades being fixed to the inner surface of a pump casing.

11. A vacuum pump according to Claim 1, wherein:

said multiple cylinder includes a pair of inner and outer cylinders arranged concentrically;
said screw pump stator includes a first screw-pump stator (21) arranged at a position facing the outer peripheral surface of said outer cylinder and a second screw-pump stator (22) arranged between said outer cylinder and said inner cylinder;
said exhaust passage of the thread-groove pump includes a first gas-exhaust passage (R1) provided between said first screw-pump

stator and said outer cylinder, a second gas-exhaust passage (R2) provided between said outer cylinder and said second screw-pump stator, and a third gas-exhaust passage (R3) provided between said second screw-pump stator and said inner cylinder, said first gas-exhaust passage and said second gas-exhaust passage being communicated under said outer cylinder and said second gas exhaust passage and said third gas exhaust passage being communicated above said second screw-pump stator.

FIG. 1

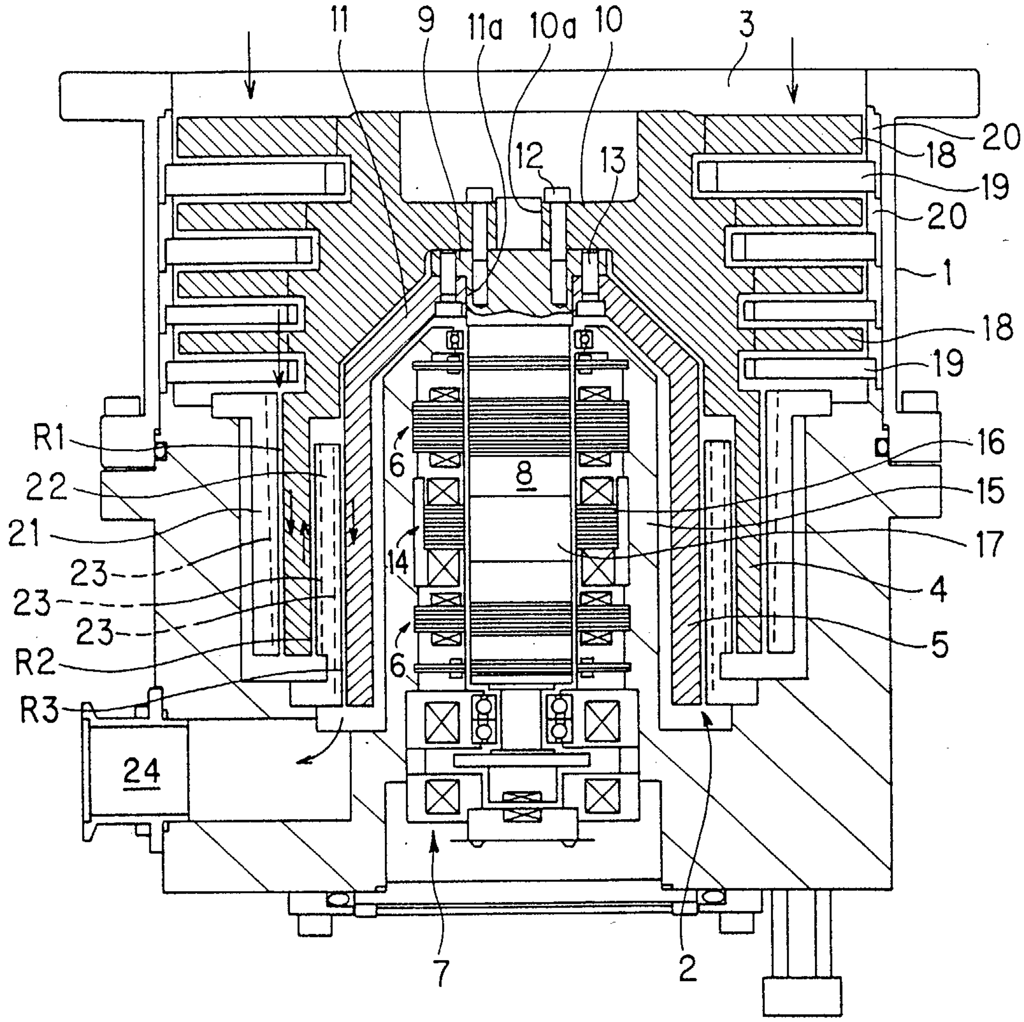

11
9
11a
10a
10
3
12
13
20
18
19
20
1
18
19
16
15
17
4
5
R1
22
21
23
23
23
R2
R3
6
8
14
6
24
7
2

FIG. 2

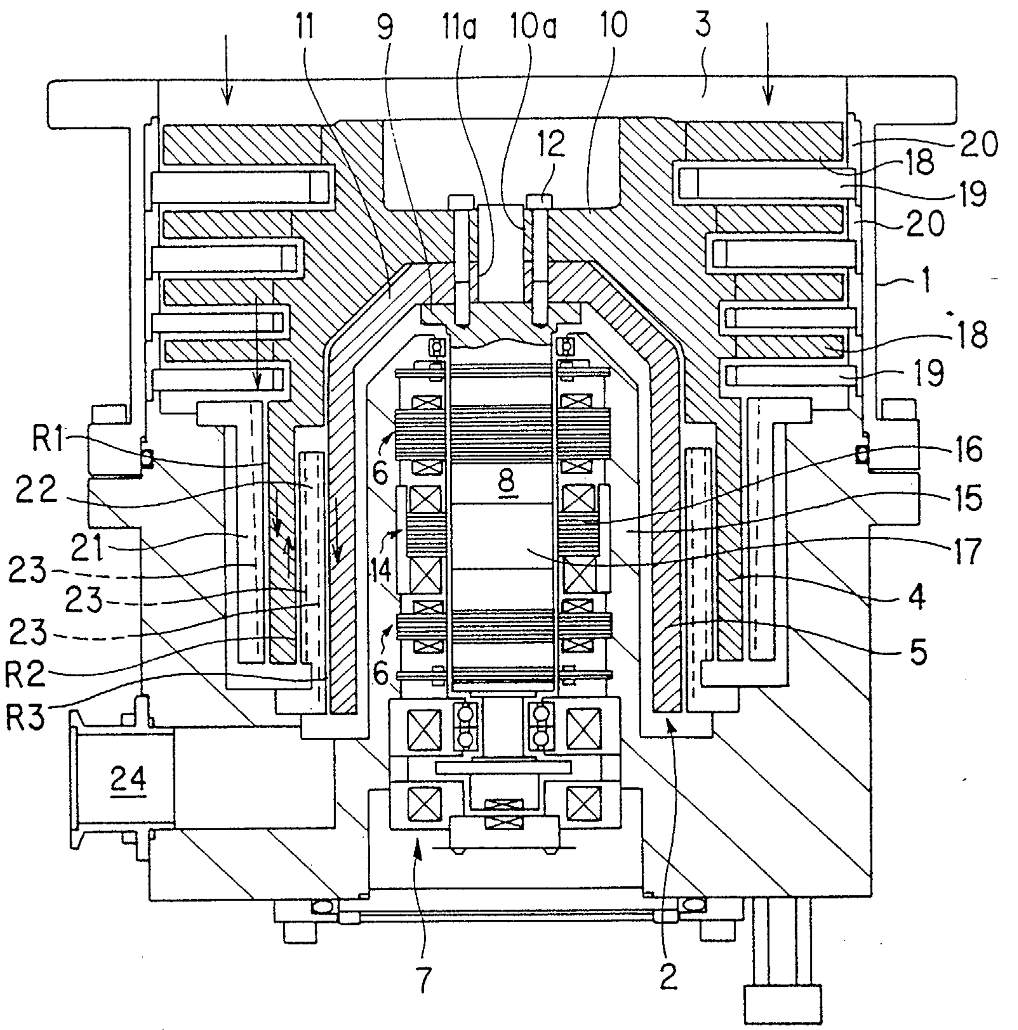
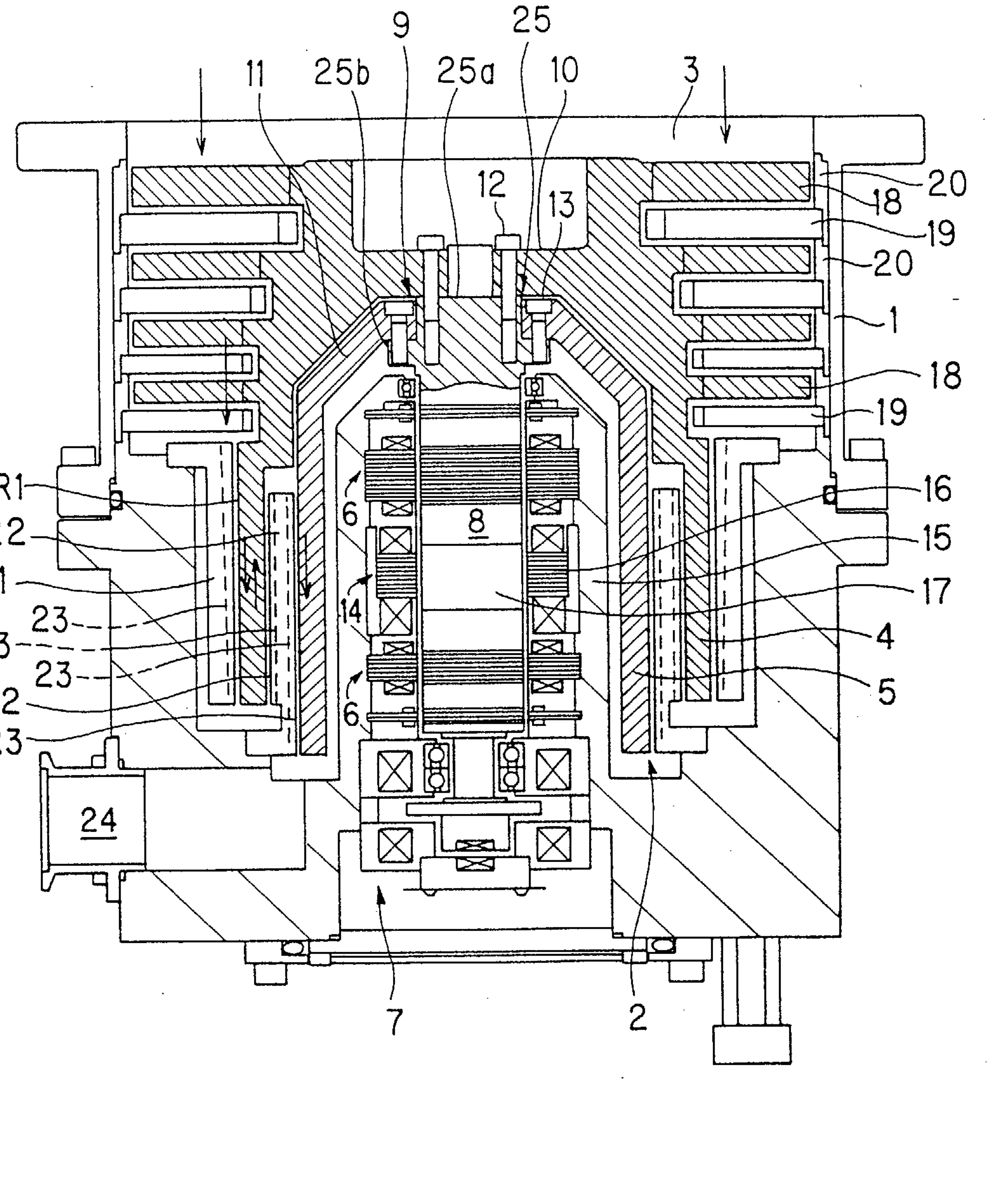

11
9
11a
10a
10
3
12
20
18
19
20
1
18
19
16
15
17
4
5
R1
22
21
23
23
23
R2
R3
6
8
14
6
24
7
2

FIG. 3


9
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11
25b
25a
10
3
12
13
20
18
19
20
1
18
19
R1
16
22
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21
17
23
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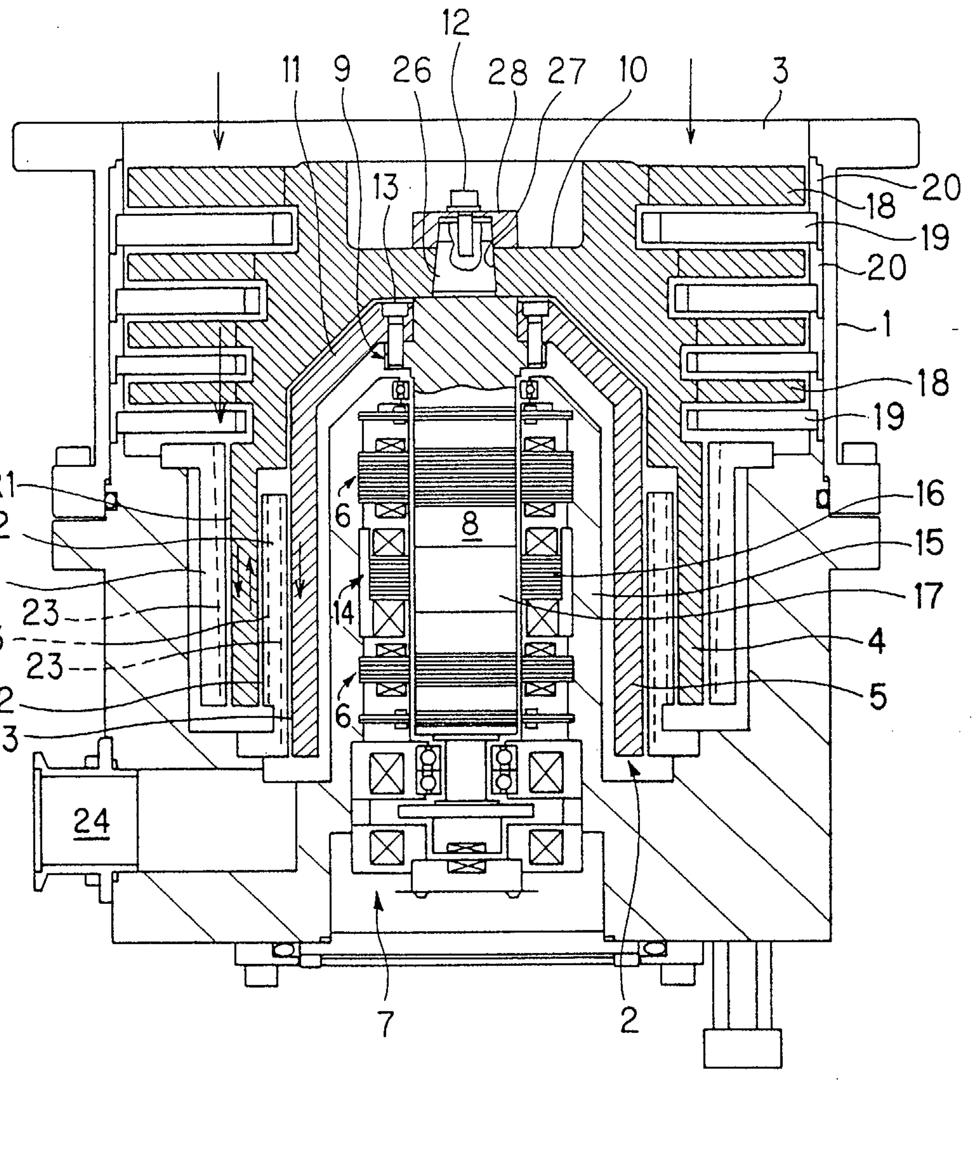
4
23
23
5
R2
R3
6
8
6
24
7
2

FIG. 4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28
27
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3
13
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18
19
20
1
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19
R1
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23
23
R2
R3
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8
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17
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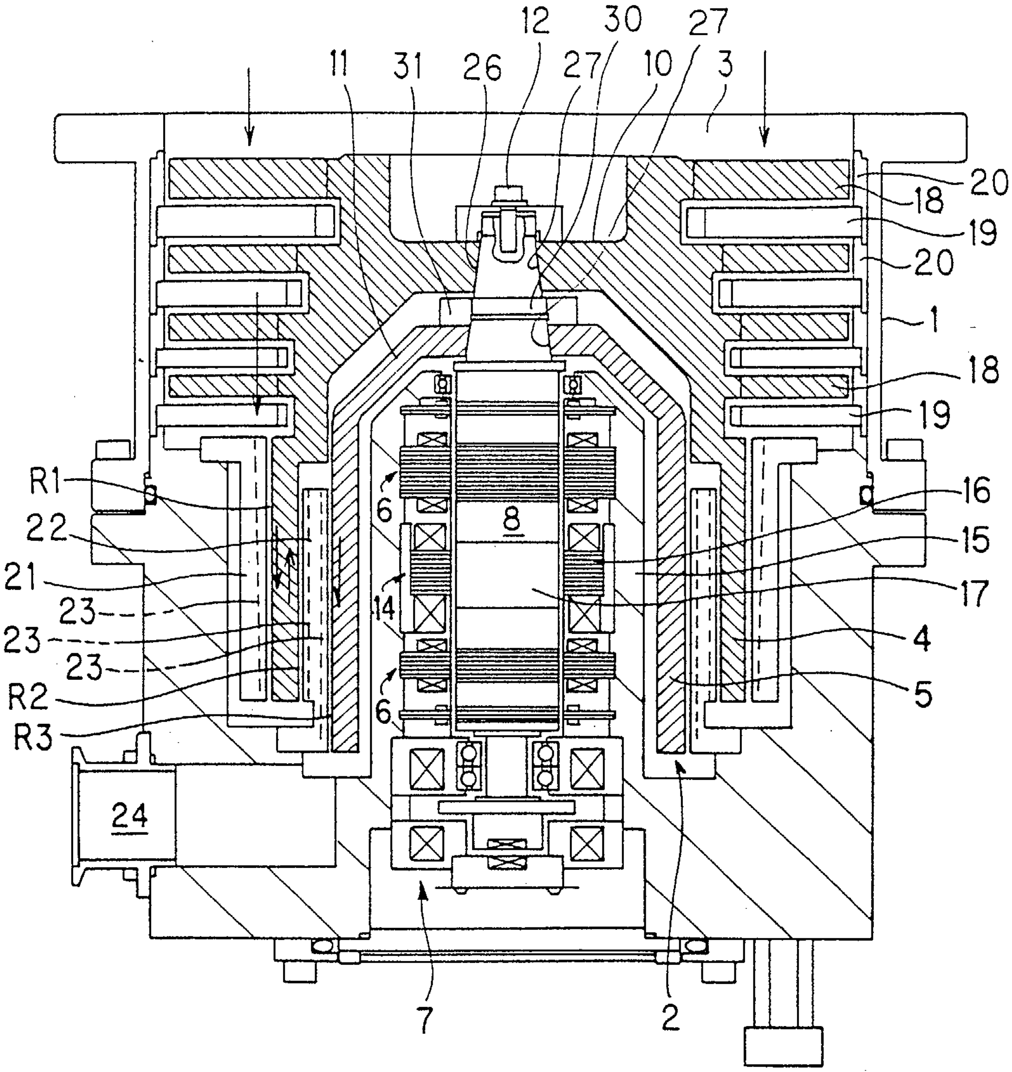
7
2

FIG. 5



12
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27
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31
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18
19
20
1
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16
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R1
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23
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R2
R3
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2

FIG. 6

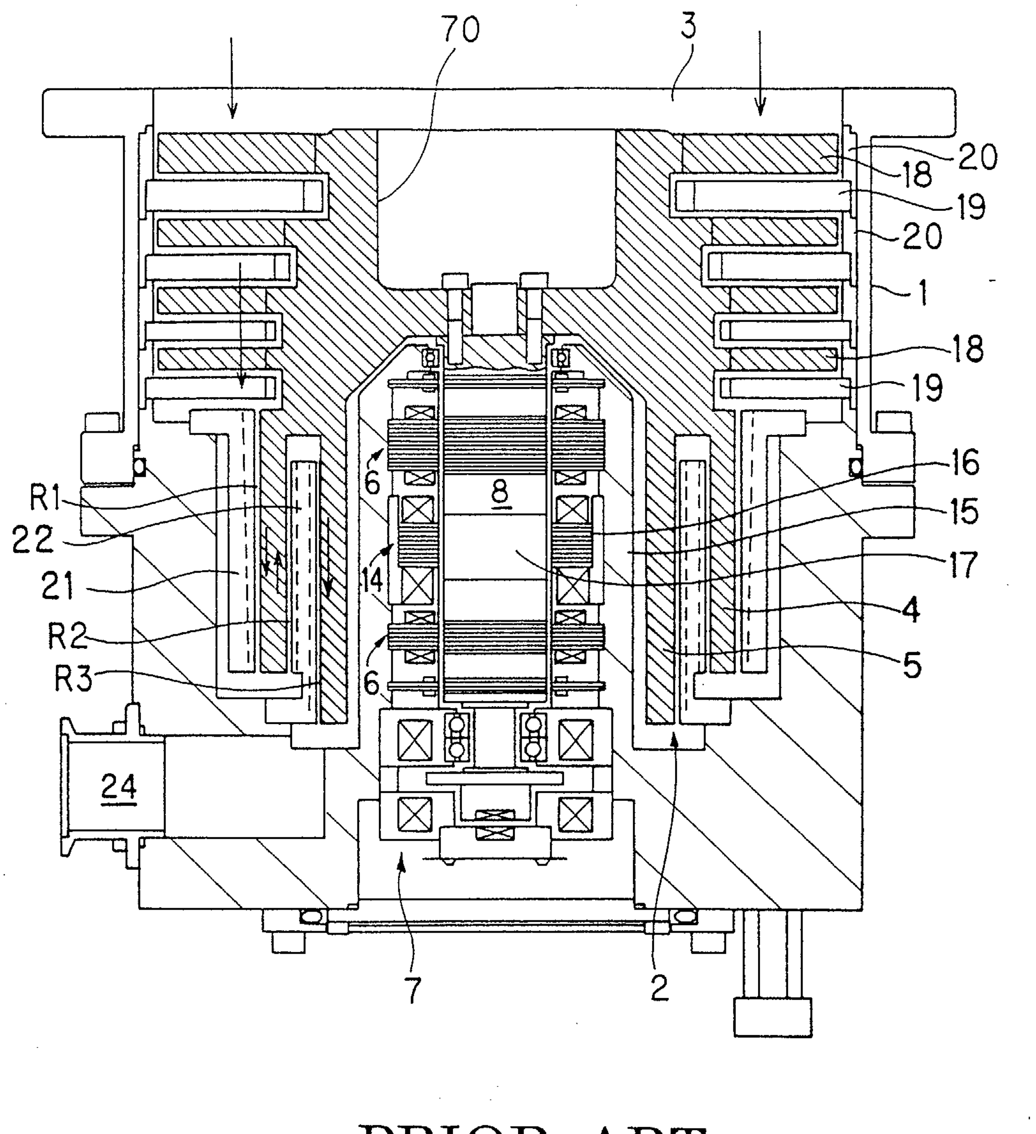

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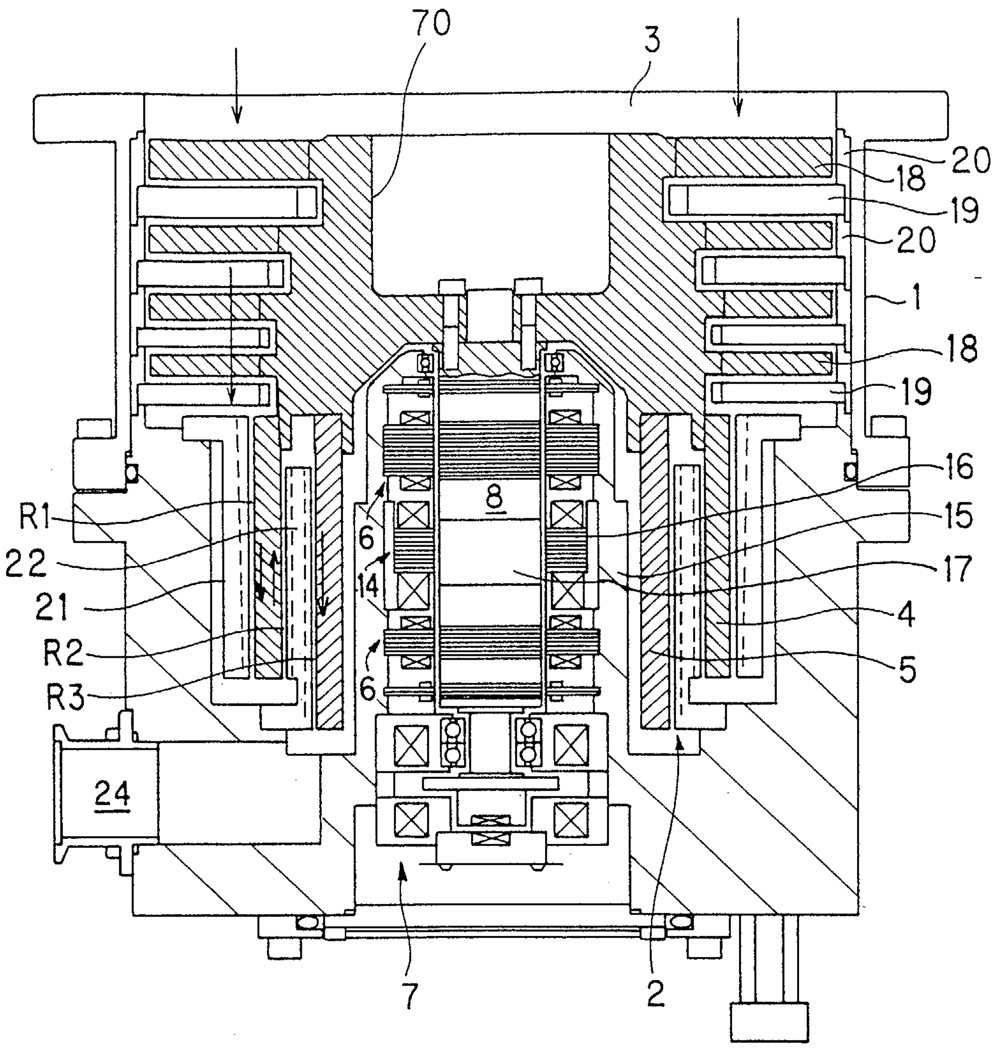
FIG. 7



PRIOR ART