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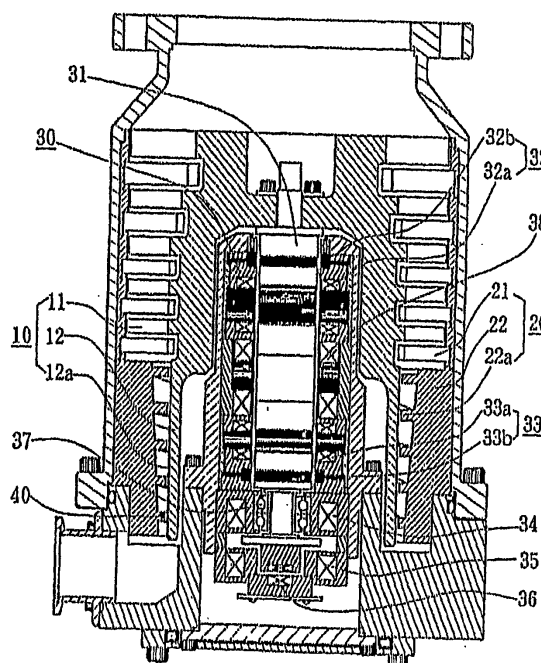
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(54) **VACUUM PUMP**

(57) Disclosed is a vacuum pump equipped with a thread groove pump portion, wherein the rotor cylindrical body and the stator cylindrical body are reliably prevented from coming abnormally close to or into contact with each other.

A composite type turbo-molecular pump is composed of a rotor cylindrical body 12 and a stator cylindrical body 22 and equipped with a thread groove pump portion in which a thread is formed in the inner peripheral surface 22a of the stator cylindrical body 22, wherein there is provided in the portion of the inner peripheral surface 22a of the stator cylindrical body 22 in the vicinity of the lower end thereof an air gap sensor for detecting an air gap formed between the outer peripheral surface 12a of the rotor cylindrical body 12 and the inner peripheral surface 22a of the stator cylindrical body 22.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a vacuum pump which is composed of a rotor cylindrical body and a stator cylindrical body and which is provided with a thread groove pump portion in which a thread is formed in either the outer peripheral surface of the rotor cylindrical body or the inner peripheral surface of the stator cylindrical body and, in particular, to a measure for preventing the rotor cylindrical body and the stator cylindrical body from coming into contact with each other.

BACKGROUND ART

[0002] Examples of a vacuum pump provided with a thread groove pump portion include a composite-type turbo-molecular pump. As is well known, a composite-type turbo-molecular pump beats down molecules by a difference in speed between rotor blades, which rotate at high speeds of several tens of thousands of revolutions per minute, and stator blades, discharging gas through a flow passage formed by a thread groove portion formed in the inner peripheral surface of the stator and the outer peripheral surface of the rotor. It consists of a combination of a turbine blade portion consisting of rotor blades in a number of stages and stator blades in a number of stages, and a thread groove pump portion consisting of a rotor cylindrical body having a flat outer peripheral surface and a stator cylindrical body having an inner peripheral surface with a thread groove. The rotor is rotatably supported by a bearing, such as a 5-axis control type magnetic bearing consisting of an active radial magnetic bearing and an active thrust magnetic bearing. There is provided a touchdown bearing for supporting the rotor shaft in an emergency such as failure of the magnetic bearing.

[0003] To prevent the outer peripheral surface of the rotor cylindrical body and the thread groove portion of the stator cylindrical body from coming into contact with each other, that is, to prevent the rotor side and the stator side from coming into contact with each other, it is desirable that the air gap between the two cylindrical bodies constituting the thread groove pump portion, that is, the air gap between the thread groove portion of the stator cylindrical body and the outer peripheral surface of the rotor cylindrical body (hereinafter abbreviated to the "thread groove pump portion air gap" as needed) be large to some degree. However, to prevent the gas taken in through the inlet of the vacuum pump from flowing in the reverse direction in the thread groove portion, that is, to improve the exhaust speed efficiency of the vacuum pump, it is desirable that the thread groove pump portion air gap be as small as possible. Taking into account these two mutually contradictory conditions and other conditions, the air gap of the thread groove pump portion is determined.

[0004] Apart from the thread groove pump portion air gap, the composite type turbo-molecular pump includes the air gap between the magnetic bearing and the rotor shaft, the air gaps between the rotor blades and the stator blades, the air gap between the inner ring of the touchdown bearing and the rotor shaft (hereinafter abbreviated to the "touchdown bearing air gap" as needed), etc.

[0005] These air gaps are also set to sizes in conformity with their respective functions and purposes so that the components may not be brought into contact with each other. It is to be noted that, of these, the touchdown bearing air gap is set to be relatively small as compared with the air gap between the magnetic bearing and the rotor shaft, the air gaps between the rotor blades and the stator blades, the thread groove pump portion air gap, and the other air gaps. The reason for this arrangement is to prevent the rotor side and the stator side from coming into contact with each other when the rotor shaft is supported by the touchdown bearing, which occurs when the magnetic bearing ceases to function as a result of failure of the vacuum pump, atmosphere intrusion, a power failure, etc.

[0006] It is to be noted, however, that the touchdown bearing is a consumable item; as the touchdown of the rotor shaft is repeated, the touchdown bearing is worn, the touchdown bearing air gap gradually increasing. When the touchdown bearing air gap has increased to become not smaller than a fixed size, it ceases to function as a touchdown bearing. Then, it can happen that the rotor side and the stator side come into contact with each other at the time of touchdown.

[0007] Further, the thread groove pump portion air gap is not always equal to the design value. Actually, it differs from product to product depending on the parts accuracy, assembly condition, etc. Further, when operating the vacuum pump, the lower portion of the rotor cylindrical body, in particular, expands radially due to centrifugal force, heat, etc., whereby not only does it reduce the thread groove pump portion air gap, but in some cases it can be brought into contact with the thread groove portion of the stator cylindrical body.

[0008] As stated above, the size of the thread groove pump portion air gap is determined such that the outer peripheral surface of the rotor cylindrical body and the thread groove portion of the stator cylindrical body are not brought into contact with each other during normal operation and at the time of touchdown, and that the gas taken in through the inlet of the vacuum pump does not flow in the reverse direction in the thread groove portion. Thus, in the above composite type turbo-molecular pump, when the magnetic bearing is functioning in the normal manner, there is no danger of the thread groove pump portion air gap being reduced to an abnormal degree, or the rotor cylindrical body and the stator cylindrical body coming into contact with each other. However, as stated above, when the touchdown bearing has been worn to increase the touchdown bearing air gap,

it can happen that the rotor side and the stator side are brought into contact with each other at the time of touchdown even when the thread groove pump portion air gap is equal to the design value.

[0009] It would be convenient if it were possible to constantly monitor the air gap of the touchdown bearing, issuing an alarm as soon as the gap has been increased to become not less than a fixed value to remind the operator to replace the parts or to stop the operation of the vacuum pump. However, in this regard, no effective solution has been found out yet. This is mainly due to the fact that the air gap of the touchdown bearing is very small.

[0010] A number of methods for constantly monitoring a magnetic bearing for malfunction have been proposed, as disclosed in Japanese Patent Application Laid-Open No. 63-239397, Japanese Patent Application Laid-Open No. 2-221697, etc. According to these methods, malfunction of the magnetic bearing is detected to mitigate the impact imparted to the touchdown bearing, thereby reducing the wear of the touchdown bearing. In this way, the rotor side and the stator side are prevented from coming into contact with each other in an indirect fashion.

[0011] However, in view of the fact that the thread groove pump portion air gap differs from product to product depending on the parts accuracy, assembly condition, etc. and that the lower portion of the rotor cylindrical body expands radially due to centrifugal force, heat, etc. when operating the vacuum pump, it will be understood that it is impossible to prevent the rotor side and the stator side from coming abnormally close to each other or coming into contact with each other by the method according to which the magnetic bearing is constantly monitored for malfunction.

[0012] It is accordingly an object of the present invention to provide a vacuum pump which is composed of a rotor cylindrical body and a stator cylindrical body and which is provided with a thread groove pump portion in which a thread is formed in either the outer peripheral surface of the rotor cylindrical body or the inner peripheral surface of the stator cylindrical body, wherein the rotor cylindrical body and the stator cylindrical body are reliably prevented from coming abnormally close to or into contact with each other.

DISCLOSURE OF THE INVENTION

[0013] In order to solve the above-mentioned problem, in a vacuum pump which is composed of a rotor cylindrical body and a stator cylindrical body and which is provided with a thread groove pump portion in which a thread is formed in any one of the outer peripheral surface of the rotor cylindrical body and the inner peripheral surface of the stator cylindrical body, an air gap sensor for detecting an air gap between the outer peripheral surface of the rotor cylindrical body and the inner peripheral surface of the stator cylindrical body is provided

at a predetermined position on the inner peripheral surface of the stator cylindrical body.

[0014] A plurality of the air gap sensors are arranged circumferentially at predetermined intervals on the inner peripheral surface of the stator cylindrical body. Further, the air gap sensor is arranged on the inner peripheral surface of the portion of the stator cylindrical body in the vicinity of the lower end thereof.

[0015] As the air gap sensor, there is employed any one of a contact sensor and an eddy current sensor. The contact sensor is constructed of a pair of contacts arranged circumferentially at a minute interval on the inner peripheral surface of the stator cylindrical body.

[0016] Furthermore, in a vacuum pump which is composed of a rotor cylindrical body and a stator cylindrical body, there is provided a contact preventing device including: an air gap sensor for detecting an air gap between the outer peripheral surface of the rotor cylindrical body and the inner peripheral surface of the stator cylindrical body; a memory for storing the air gap value detected by the air gap detector; a discriminating device for comparing the detected air gap value with a set value; and an interlock circuit which causes an interlock operation to start when it is determined by the discriminating device that the detected air gap value is not higher than the set value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Fig. 1 is a longitudinal sectional view of a vacuum pump according to an embodiment of the present invention which consists of a composite type turbo-molecular pump formed by combining a turbine blade portion with a thread groove pump portion.

Fig. 2 is an enlarged partial view of the rotor cylindrical body and the stator cylindrical body in the thread groove pump portion.

Fig. 3 is a partial perspective view of the inner peripheral surface of the stator cylindrical body in the thread groove pump portion.

Fig. 4 is a block diagram of an embodiment of a contact preventing device.

Fig. 5 is a flowchart illustrating the operation of the contact preventing device.

BEST MODE FOR CARRYING OUT THE INVENTION

[0018] A preferred embodiment of the present invention will now be described in detail with reference to Figs. 1 through 5.

[0019] Fig. 1 is a longitudinal sectional view of a composite type turbo-molecular pump according to an embodiment of the present invention. This composite type turbo-molecular pump is a large capacity type turbo-molecular pump formed by combining a turbine blade portion with a thread groove pump portion, and comprises

a rotor 10, a stator 20, and a magnetic bearing device 30 rotatably supporting the rotor 10. The rotor 10 includes rotor blades 11 in a number of stages and a rotor cylindrical body 12 having a flat outer peripheral surface 12a. The stator 20 includes stator blades 21 in a number of stages and a stator cylindrical body 22 having an inner peripheral surface 22a with a thread groove. The rotor blades 11 in a number of stages and the stator blades 21 in a number of stages constitute the turbine blade portion, and the rotor cylindrical body 12 having the flat outer peripheral surface 12a and the stator cylindrical body 22 having the inner peripheral surface 22a with a thread groove constitute the thread groove pump portion.

[0020] The magnetic bearing device is a so-called 5-axis control type magnetic bearing device, and comprises a rotor shaft 31, a first radial magnetic bearing 32 consisting of a radial electromagnet 32a and a radial displacement sensor 32b, a second radial magnetic bearing 33 consisting of a radial electromagnet 33a and a radial displacement sensor 33b, a first thrust magnetic bearing 34 including an axial electromagnet, a second thrust magnetic bearing 35 including an axial electromagnet, an axial displacement sensor 36, a touchdown bearing 37, and a high frequency motor 38.

[0021] A gap sensor 40 according to the present invention serves to detect the air gap in the thread groove pump portion formed by the rotor cylindrical body 12 having the flat outer peripheral surface 12a and the stator cylindrical body 22 having the thread-grooved inner peripheral surface 22a. That is, it detects the air gap g shown in Fig. 2, which is an enlarged partial sectional view of the rotor cylindrical body and the stator cylindrical body in the thread groove pump portion. As is apparent from Fig. 2 and Fig. 3, which is a partial perspective view of the inner peripheral surface of the stator cylindrical body in the thread groove pump portion, the air gap g is formed in a spiral shape in the substantially cylindrical gap between the outer peripheral surface 12a of the rotor cylindrical body 12 and the inner peripheral surface 22a of the stator cylindrical body 22.

[0022] In the composite type turbo-molecular pump shown in Fig. 1, the air gap sensor 40 is installed on the thread-grooved inner peripheral surface 22a of the stator cylindrical body 22, as shown in Fig. 3. The air gap sensor 40 consists, for example, of a contact sensor or an eddy current sensor.

[0023] To prevent the stator cylindrical body 22 and the rotor cylindrical body 12 from coming into contact with each other as a result of the precession of the rotor 10, it is desirable to perform air gap detection at a plurality of positions in the same circumference. When using a plurality of air gap sensors 40 in order to improve the accuracy in gap detection, these sensors are arranged circumferentially at predetermined intervals on the thread-grooved inner peripheral surface 22a of the stator cylindrical body 22.

[0024] Further, the lower end portion of the rotor cy-

lindrical body 12, which is most spaced apart from the rotor shaft 31, is, as compared with the other portions, more likely to undergo great displacement and come into contact with the stator side when an abnormal contact rotation occurs. In view of this, the air gap sensor 40 is arranged on the inner peripheral surface of the portion of the stator cylindrical body 22 in the vicinity of the lower end thereof, thereby achieving an improvement in terms of reliability in gap detection.

[0025] When a contact sensor 41 is used as the air gap sensor 40, a pair of contacts 41a and 41b constituting the contact sensor 41 are arranged circumferentially at a minute interval on the inner peripheral surface 22a of the stator cylindrical body 22, as shown in Fig. 3. That is, the air gap sensor having the first contact 41a is arranged on a thread groove portion B, and the air gap sensor having the second contact 41b is arranged on a thread ridge portion A. The contacts are arranged on the inner peripheral surface 22a of the stator cylindrical body 22 such that they are in the same circumference in the gap between the stator cylindrical body 22 and the rotor cylindrical body 12, that is, the respective distances from the central axis of the stator cylindrical body 22 to the contacts are the same. Thus, the second contact 41b protrudes to some degree from the thread ridge A, whereas the first contact 41a protrudes to a considerable degree from the thread groove B. Due to this arrangement, when the rotor 10 is supported in the normal position, the respective distances from the outer peripheral surface of the rotor cylindrical body 12 to the contacts are the same.

[0026] Since the contact sensor 41 is arranged in the manner as described above, when the cylindrical body 12 of the rotor 10 formed of a metal such as aluminum comes into contact with the contact sensor 41 on the stator cylindrical body 22 side, the contacts 41a and 41b of the contact sensor 41 are electrically connected to each other to issue a detection signal. This detection signal indicates that the air gap of the thread groove pump portion has become abnormally small, and consequently, there is a greater danger of the inner peripheral surface of the rotor cylindrical body coming into contact with the inner peripheral surface of the stator cylindrical body 22.

[0027] It is possible to use an eddy current sensor 42 as the air gap sensor 40. In this case, the eddy current sensor 42 is installed on the thread-grooved inner peripheral surface 22a of the stator cylindrical body 22 like the contact sensor 41. Unlike the contact sensor 41, the eddy current sensor 42 is capable of detecting an air gap value indicating the size of the air gap g .

[0028] Fig. 4 is a block diagram of a contact preventing device formed by using the eddy current sensor 42 as the air gap sensor 40, and Fig. 5 is a flowchart showing the operation thereof. In Fig. 4, the contact preventing device comprises the eddy current sensor 42 for detecting the air gap, a CPU 43 for performing various computing and control operations according to a pro-

gram, a setting unit 45 serving as an input means for providing a set value, etc., and an interlock circuit 46 for bringing the operation of the vacuum pump to an emergency stop.

[0029] When the contact preventing device starts (101), the CPU 43 reads the air gap value from the eddy current sensor 42, and stores it in a memory 44 (102). Next, the CPU 43 reads a set value and an air gap value from the memory 44, and compares them with each other (103). When, as a result of the comparison, it is determined that the air gap value is not larger than the set value, the interlock circuit is operated, and the operation of the vacuum pump is brought to an emergency stop (104), thereby completing the operational flow (105). It is also possible to provide the contact preventing device with an alarm unit, which issues an alarm when the air gap value becomes not larger than the set value. Further, it is also possible to use the contact sensor 41 as the air gap sensor and form a simplified contact preventing device which detects contact of the inner peripheral surface 12a of the rotor cylindrical body 12 with the contacts 41a and 41b of the sensor portion and issues an alarm.

[0030] While in the above-described embodiment the present invention is applied to a vacuum pump provided with a thread groove pump portion in which a thread groove is formed on the stator side, it is also possible to apply the present invention to a vacuum pump in which a thread is formed on the outer peripheral surface of the rotor cylindrical body and in which this thread-grooved outer peripheral surface is opposed to a flat inner peripheral surface of the stator cylindrical body, there being provided a thread groove pump portion which maintains a predetermined air gap therebetween.

[0031] Further, the present invention is also applicable to a vacuum pump in which the rotor is supported by a mechanical bearing, such as a rolling bearing or a sliding bearing. It goes without saying that the present invention is applicable to vacuum pumps in general including turbo-molecular pumps and drag pumps.

INDUSTRIAL APPLICABILITY

[0032] In accordance with the present invention, there is provided a vacuum pump provided with a thread groove pump portion, wherein an air gap sensor is provided at a predetermined position of the inner peripheral surface of the stator cylindrical body, whereby it is possible to directly and reliably detect the air gap between the outer peripheral surface of the rotor cylindrical body and the inner peripheral surface of the stator cylindrical body. Further, by operating the interlock by utilizing the output signal of the air gap sensor, it is possible to reliably prevent the rotor side and the stator side from coming into contact with each other. Thus, an improvement in terms of reliability and durability has been achieved in a vacuum pump provided with a thread groove pump portion.

[0033] Further, the air gap sensor is something that is easily obtained, and the requisite number of man-hours for installing it in the thread groove pump portion is small, so that there is involved little increase in the production cost of a vacuum pump to which the present invention is applied, which leads to a substantial practical advantage.

Claims

1. A vacuum pump which is composed of a rotor cylindrical body and a stator cylindrical body and which is provided with a thread groove pump portion in which a thread is formed in either the outer peripheral surface of the rotor cylindrical body or the inner peripheral surface of the stator cylindrical body, wherein an air gap sensor for detecting an air gap between the outer peripheral surface of the rotor cylindrical body and the inner peripheral surface of the stator cylindrical body is provided at a predetermined position on the inner peripheral surface of the stator cylindrical body.
2. A vacuum pump according to Claim 1, wherein a plurality of the air gap sensors are arranged circumferentially at predetermined intervals on the inner peripheral surface of the stator cylindrical body.
3. A vacuum pump according to Claim 1, wherein the air gap sensor is arranged on the inner peripheral surface of the portion of the stator cylindrical body in the vicinity of the lower end thereof.
4. A vacuum pump according to Claim 1, wherein the air gap sensor is a contact sensor having a pair of contacts arranged circumferentially at a minute interval on the inner peripheral surface of the stator cylindrical body.
5. A vacuum pump according to Claim 1, wherein the air gap sensor is an eddy current sensor.
6. A vacuum pump which is composed of a rotor cylindrical body and a stator cylindrical body and which is provided with a thread groove pump portion in which a thread is formed in either the outer peripheral surface of the rotor cylindrical body or the inner peripheral surface of the stator cylindrical body, the vacuum pump further comprising: a contact preventing device comprising an air gap sensor for detecting an air gap between the outer peripheral surface of the rotor cylindrical body and the inner peripheral surface of the stator cylindrical body; a memory for storing the air gap value detected by the air gap detector; a discriminating device for comparing the detected air gap value with a set value; and an interlock circuit which causes an inter-

lock operation to start when it is determined by the discriminating device that the detected air gap value is not higher than the set value.

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FIG. 1

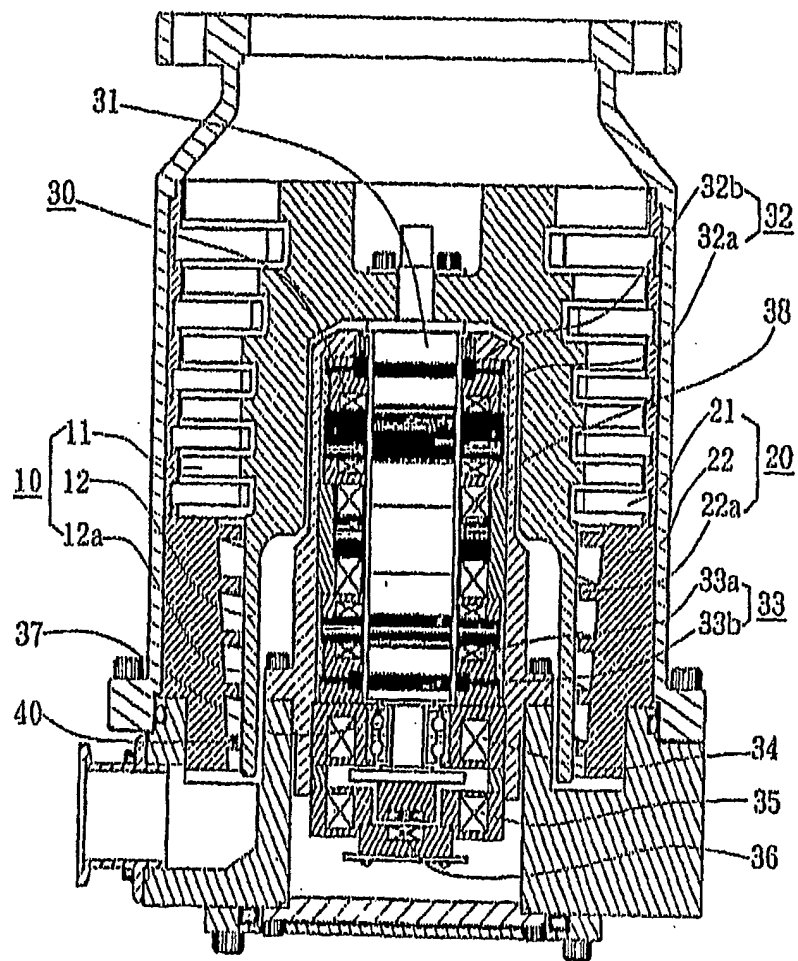


FIG. 2

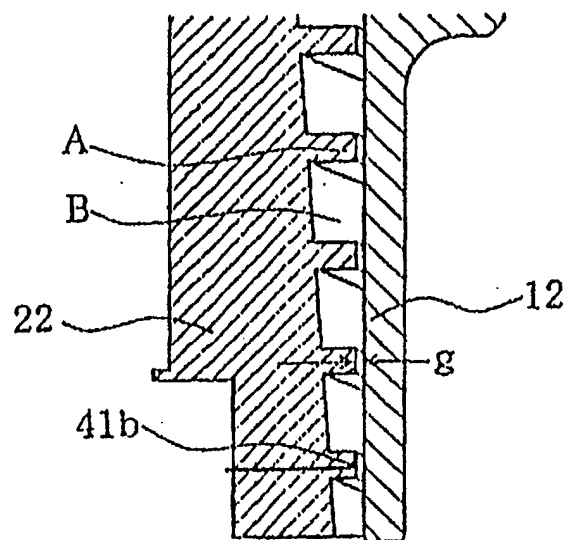


FIG. 3

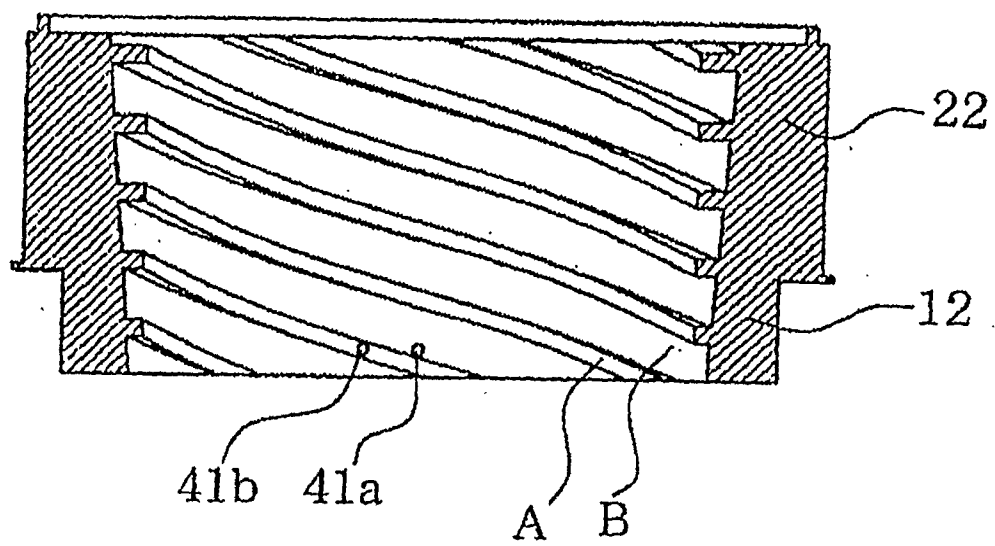


FIG. 4

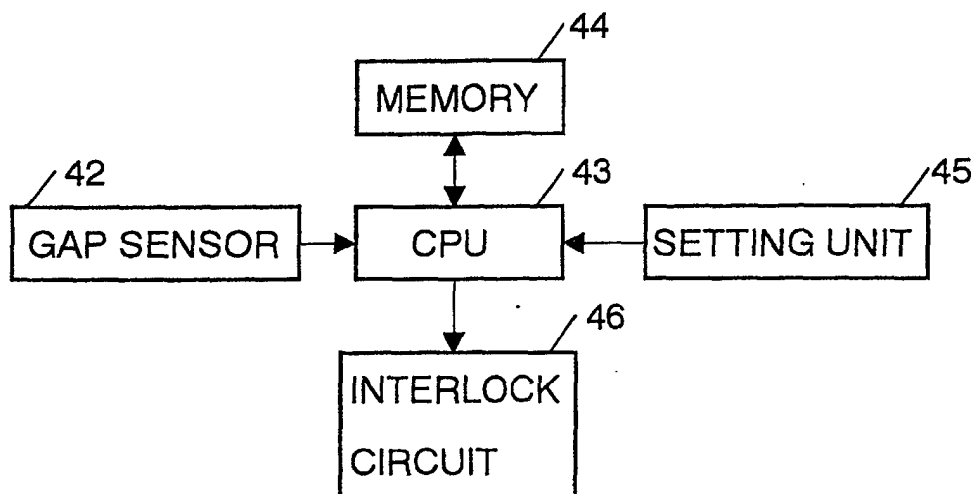
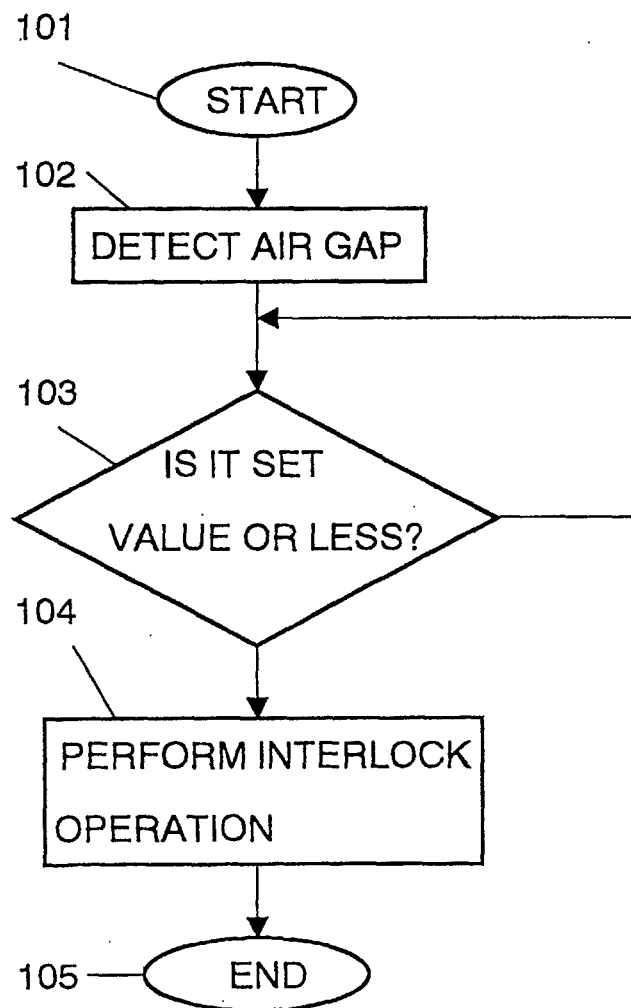


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/02061

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ F04D19/04		
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 F04D19/04		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 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.
X	JP, 11-6774, A (Daikin Industries, Ltd.),	1
Y	12 January, 1999 (12.01.99), Full text; Figs. 1 to 7 (Family: none)	2-5
P,X	JP, 11-280690, A (Ebara Corporation),	1, 5
P,Y	15 October, 1999 (15.10.99), Full text; Figs. 1 to 3 (Family: none)	2-4
X	JP, 11-72097, A (Kashiyama Kogyo K.K.), 16 March, 1999 (16.03.99), Full text; Figs. 1 to 3 (Family: none)	6
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No.200279/1983 (Laid-open No.104107/1985) (GE YOKOGAWA MEDICAL SYSTEMS, LTD.), 16 July, 1985 (16.07.85), Full text; Figs. 1 to 6 (Family: none)	4
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 26 June, 2000 (26.06.00)		Date of mailing of the international search report 11 July, 2000 (11.07.00)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
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