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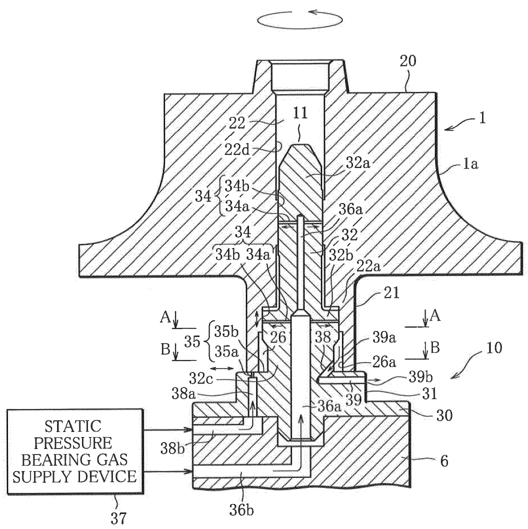
(54) SUPPORT DEVICE FOR BALANCE CORRECTION

(57) The support apparatus for balance correction of the present invention provides a vent hole (38) at a position facing a polygon-shaped cross-section portion (26a) of a support hole, of an outer peripheral surface of a mandrel (11) on which the support hole (22) of a rotating body (1) having a portion (26) formed in a polygonal cross-sectional shape on an end side is mounted. The vent hole (38) relieves pressure varying in a space between the polygon-shaped cross-section portion and the outer peripheral surface of the mandrel outside according to the rotation of the rotating body.

FIG. 2



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Description

Technical Field

[0001] The present invention relates to a support apparatus for balance correction for rotatably supporting a rotating body using a vertical mandrel having an aerostatic bearing in order to correct the balance of the rotating body rotating at high speeds such as a turbocompressor rotor.

Background Art

[0002] It is known about the turbocompressor rotor rotating at high speeds (corresponding to the rotating body of the present application) that in order to eliminate imbalance (dynamic imbalance) caused by component tolerance at manufacturing, a balance correction apparatus is commonly used to measure the amount of imbalance, and then to correct the imbalance.

[0003] In order to allow the balance correction apparatus to measure the amount of imbalance with a high accuracy, there is used a support apparatus (support apparatus for balance correction) for rotatably supporting the rotor alone using a mandrel having an aerostatic bearing. As disclosed in Figure 5 of Patent Document 1, most of the support apparatuses have a structure such that as the mandrel, there is used a cylindrical mandrel member which is fitted into a support hole with a circular cross section located at a rotation axis portion of the rotor, aerostatic radial bearings (each having radial bearing surface including a jet hole) are provided on an outer peripheral surface of the mandrel member, and aerostatic thrust bearings (each having a thrust bearing surface including a jet hole) are provided on the base end side of the mandrel member.

[0004] When the mandrel is fitted into the support hole of the rotor, the structure allows the entire rotor to be mounted on the mandrel. Then, compressible fluid (air for aerostatic bearings) is jetted onto internal surfaces of the support hole through the jet holes of the aerostatic radial bearings, and compressible fluid (air for aerostatic bearings) is jetted onto the periphery of the opening (end surface of the rotor) at the lower end of the support hole through the jet holes of the aerostatic thrust bearings, whereby the rotor is rotatably supported around the mandrel in a floating state.

[0005] The amount of imbalance (amount of dynamic imbalance) is measured by applying rotational force to the rotor in the floating state from outside, such as by jetting air for drive (drive fluid) onto the rotor surface, to rotate the rotor at high speeds, and then using various sensors provided in the balance correction apparatus to measure the behavior of the rotating rotor.

Prior Art Document

Patent Document

[0006] Patent Document 1: Japanese Patent Laid-Open No. 2005-172538 (Figure 5)

Summary of the Invention

Problems to be solved by the Invention

[0007] As disclosed in Patent Document 1, the support hole of the rotor is generally a hole having a cylindrical shape with a circular cross section, that is, a circular cross section in an entire axial direction. The reason for this is to fittingly insert the end of the shaft mating with the rotor into the support hole and to couple the shaft with the rotor by bolts or the like.

[0008] By the way, there has been an increasing demand from various system fields using the turbocompressor for the turbocompressor rotor, such as allowing the rotor to be firmly coupled with the shaft, allowing the rotor axis to be aligned with the shaft axis with a high accuracy, and other requests.

[0009] In view of this, in order to meet such demands for the turbocompressor rotor, there has recently been proposed a structure of a coupling system of coupling by fittingly inserting the shaft into the rotor using a polygonal shaped portion, in addition to coupling by a hole with a circular cross section. In order to achieve the coupling system, it is beginning to be considered that an inner hollow portion with a polygon-shaped cross section into which a polygonal shaped portion formed on the shaft is fitted is formed on an end side of the support hole of the rotor.

[0010] However, if a support hole having a polygonal shaped inner hollow portion is employed, the amount of imbalance of the rotor may not be satisfactorily measured.

[0011] Specifically, when the amount of imbalance of the rotor is measured, compressible fluid jetted through the jet holes of the aerostatic bearings generally fills between an outer peripheral surface of the mandrel and an inner surface of the support hole serving as a portion supporting the rotor by aerostatic gas.

[0012] At this time, if the support hole has the same shape with a circular (perfect circular) cross section as the outer peripheral shape of the mandrel, a rotation of the rotor causes no pressure variation, thereby ensuring high measurement accuracy. However, if the support hole has a polygon-shaped inner hollow portion, squeeze occurs between the polygon-shaped portion and the outer peripheral surface of the mandrel according to the rotation (displacement) of the rotor unlike the case where the support hole has the circular (perfect circular) cross section. The squeeze effect at this time causes pressure to repeatedly increase and decrease between the same.

[0013] The rotor supported by the mandrel generates hunting vibration due to this pressure variation. This vibration tends to impair the accuracy of measuring the amount of imbalance of the rotor. This vibration also poses a problem in that the rotor is likely to contact the mandrel, which may prevent satisfactory measurement of the amount of imbalance as desired.

[0014] In view of this, an object of the present invention is to provide a support apparatus for balance correction capable of measuring the amount of imbalance of a rotating body having a support hole including a polygonal shaped portion with a high accuracy.

Means for Solving the Problems

[0015] The present invention provides a vent hole for relieving pressure outside according to a rotation of a rotating body, the pressure varying in a space between a polygon-shaped cross-section portion of the rotating body and an outer peripheral surface of a mandrel, the vent hole being provided on the outer peripheral surface portion facing the polygon-shaped cross-section portion of a support hole, of the outer peripheral surface of a vertical mandrel on which the support hole of the rotating body having the polygon-shaped cross-section portion on an end side thereof is mounted (Claim 1).

[0016] Even if part of the support hole is formed in a polygonal cross-sectional shape, the above configuration allows variation in pressure occurring in a space between the polygon-shaped cross-section portion of the support hole and the outer peripheral surface of the mandrel to be relieved outside through the vent hole when the amount of imbalance (amount of dynamic imbalance) is measured. This configuration can suppress pressure variation between the polygon-shaped cross-section portion of the support hole and the outer peripheral surface of the mandrel due to squeeze, allowing the amount of imbalance of the rotating body to be measured with a high accuracy.

[0017] Preferably, in addition to the above object, further so as to evenly relieve the varied pressure, the vent hole comprises a large number of vent holes provided at equal intervals along a circumferential direction on the outer peripheral surface of the mandrel (Claim 2).

[0018] Preferably, in addition to the above object, further so as to evenly relieve the varied pressure, the vent hole is a path formed by a shortest route, the path having an inlet near a lowest position in a space between the polygon-shaped cross-section portion and the outer peripheral surface of the mandrel, of the mandrel, the path having an outlet at a position facing outside near the aerostatic thrust bearing surface (Claim 3).

Advantageous Effects of the Invention

[0019] According to the present invention, when the amount of imbalance of the rotating body is measured, the variation in pressure occurring in a space between the polygon-shaped cross-section portion of the support hole and the outer peripheral surface of the mandrel is relieved outside through the vent holes. This configuration can suppress the pressure variation in a space between the polygonal shape cross-section portion of the support hole and the outer peripheral surface of the mandrel due to squeeze.

[0020] Therefore, the present invention can measure the amount of imbalance of the rotating body having a support hole, part of which is formed in a polygonal shape, with a high accuracy. In addition, the present invention can avoid a risk that the rotating body may contact the mandrel. Further, the present invention requires only a simple structure (Claim 1).

[0021] In addition to the above effect, further the present invention can evenly relieve the varied pressure from within a space between the polygonal shape cross-section portion and the outer peripheral surface of the mandrel through a large number of vent holes, thereby further exerting much higher effects (Claim 2).

[0022] In addition to the above effect, further the present invention form the vent holes on the shortest route, which makes it much easier to relieve pressure outside, thereby further exerting much higher effects (Claim 3).

Brief Description of the Drawings

[0023]

FIG. 1 is a perspective view illustrating a support apparatus for balance correction according to an embodiment of the present invention together with a balance correction apparatus to which the same apparatus is applied.

FIG. 2 is a sectional view illustrating a structure of each portion of the support apparatus for balance correction together with a state in which a rotor (rotating body) is mounted on a mandrel.

FIG. 3 is a sectional view along line A-A of Figure 2.

FIG. 4 is a sectional view along line B-B of Figure 2.

FIG. 5 is a sectional view for describing a behavior in a space between a polygon-shaped cross-section portion of a support hole and an outer peripheral surface of the mandrel when the rotor is rotated.

FIG. 6 is a perspective view for describing the rotor (rotating body) of a turbocompressor when the amount of imbalance is measured.

FIG. 7 is a perspective view for describing a coupling structure using the polygonal shaped portion of the rotor.

Mode for Carrying out the Invention

[0024] Hereinafter, the present invention will be described based on an embodiment illustrated in FIGS. 1 to 7.

[0025] FIG. 1 illustrates a schematic configuration of a balance correction apparatus for measuring the amount of imbalance (amount of dynamic imbalance) of a rotating body such as a turbocompressor rotor 1 (e.g., compressor rotor), in which reference numeral 2 denotes a base plate of the apparatus, reference numeral 3 denotes a frame body standingly disposed on an upper surface of the base plate 2, and reference numeral 4 denotes a vibration bridge body disposed in front of the frame body 3.

[0026] Each portion of the vibration bridge body 4 is coupled with a plurality of support spring members 5a protruding from the front surface of the frame body 3 and support spring members 5b (only some of them being illustrated) protruding from the upper surface of the base plate 2 so as to displaceably support the entire vibration bridge body 4 leftward and rightward. A support arm body 6 extends in a band shape from a front portion of the vibration bridge body 4. A support apparatus 10 (corresponding to the support apparatus for balance correction of the present application) for supporting the turbocompressor rotor 1 is mounted on a front end portion of the band-shaped support arm body 6.

[0027] By the way, various sensors 8 for detecting vibration transmitted to the vibration bridge body 4 are installed on a side of the vibration bridge body 4, and a pair of jet head portions 9 (rotational force applying portion) for jetting compressed air to rotate the rotor 1 are installed around the support apparatus 10. In FIG. 1, reference numeral 8a denotes a mounting member for mounting the various sensors 8 on the base plate 2, and reference numeral 9a denotes a mounting member for mounting the jet head portion 9 on the base plate 2.

[0028] The above support apparatus 10 uses a structure using the vertical mandrel 11 for rotatably supporting the rotor 1 (single body) by aerostatic bearings. The structure of the support apparatus 10 is illustrated in FIG. 2.

[0029] Here, before describing the structure of the support apparatus 10, the rotor 1 serving as a component to be measured will be described. For example, as illustrated in FIG. 6, the rotor 1 includes a rotor body 20 in which a large number of blades 1a are formed on a disc-shaped base surface portion 20a. The rotor body 20 includes a cylindrical boss portion 21 formed at a center portion of the base surface portion 20a. The rotation axis portion of the rotor body 20 and the boss portion 21 of the base surface portion 20a include a support hole 22 having a circular cross section and penetrating the portions in a straight line. The support hole 22 includes therein a shaft 23 having a circular cross section and mating with the rotor 1. Specifically, an end portion of the shaft 23 is inserted into the support hole 22, and the insertion end is fixed by a fixing member such as a nut member (not illustrated), whereby the rotor 1 is tightened between a receiving portion 23a receiving the end of the boss portion 21, thereby forming a module incorporating the rotor 1, that is, a rotor module.

[0030] Here, in order to couple the rotor 1 with the shaft 23, a structure having a polygonal shaped portion constituting part of the shaft 23 and support hole 22 is used (for example, for strong coupling, high precision axis alignment, and other purposes).

[0031] Specifically, in general, the support hole 22 including an inner hollow portion having a circular cross section and covering the entire rotor 1 from one end to the other end thereof, and the shaft 23 having a circular cross section and corresponding to the support hole 22 are used. However, here, as illustrated in FIGS. 6 and 7, an end constituting part of the support hole 22, specifically, an inner surface of the boss portion 21 serving as the base end of the support hole 22 includes therein a triangular inner surface 26a as a polygon-shaped cross-section portion larger than the other inner hollow with a circular cross section, and the inside of the inner surface 26a is used as the triangular inner hollow portion 26. The shaft 23 includes a triangular flange portion 27 fitted into the triangular inner hollow portion 26. In other words, the rotor 1 and the shaft 23 are coupled with each other using a structure of fitting the triangular inner hollow portion 26 and the flange portion 27 to each other.

[0032] The support apparatus 10 illustrated in FIGS. 1 and 2 includes a structure for stably supporting the rotor 1 using the support hole 22, part of which is formed in a polygonal shape.

[0033] With reference to FIGS. 1 and 2, each portion of the support apparatus 10 will be described. Reference numeral 11 denotes the aforementioned mandrel. The mandrel 11 includes a cylindrical mandrel member. The mandrel member is standingly disposed on an upper surface of a front end portion of the support arm body 6 so that the rotor 1 is mounted thereon from above the mandrel 11.

[0034] Specifically, the mandrel 11 includes a mounting seat 30 fixed on the support arm body 6, a disk-shaped portion 31 receiving the lower end of the rotor 1 (end of the boss portion 21), and a cylindrical portion 32 insertable into the rotor 1, in the order starting from the lower end thereof, and the mandrel 11 extends by a predetermined amount in the vertical direction from the support arm body 6. Specifically, of the cylindrical portion 32, a portion on which the rotor body 20 on the front end side is mounted (except the boss portion 21) includes a pillar portion 32a with a circular cross section corresponding to the shape of a small diameter hole portion 22d occupying most of the support hole 22 of the rotor body 20. As illustrated in FIG. 3, the portion on which the boss portion 21 on the base end side is mounted includes a pillar portion 32b having a diameter larger than that of the pillar portion 32a so as to fit the shape of a stepped portion 22a of the support hole 22. In particular, as illustrated in FIG. 4, the portion corresponding to a triangular inner hollow portion 26 (inner surface 26a) includes a pillar portion 32c (having a diameter smaller than that of the inner surface 26a) having a diameter smaller than that of the pillar portion 32b. As illustrated in FIG. 2, the rotor 1 can be mounted around the mandrel 11 simply by inserting the mandrel 11 into the rotor 1 from an end (base end) of the support hole 22 without being affected by the presence or absence of the triangular inner hollow portion 26.

[0035] In addition, an outer peripheral surface of the pillar portions 32a and 32b of the mandrel 11 includes aerostatic radial bearing surfaces 34b each having a large number of jet holes 34a to form an aerostatic radial bearing 34 receiving the inner surface of the support hole 22. The upper surface of the disk-shaped portion 31 includes an aerostatic thrust bearing surface 35b having a large number of jet holes 35a around the axis corresponding to the position of the end of the boss portion 21 to form therein an aerostatic thrust bearing 35 receiving the end surface (periphery of the opening of the support hole 22) of the boss portion 21 serving as the lower end of the rotor 1.

[0036] As illustrated in FIG. 2, of them, the jet hole 34a is connected to an outside static pressure bearing gas supply device 37 through a path 36a having various hole diameters and formed along an axial portion of the mandrel 11 and a relay path 36b formed inside the support arm body 6. In addition, the jet hole 35a is connected to the aforementioned static pressure bearing gas supply device 37 through a path 38a formed in the disk-shaped portion 31 and a relay path 38b formed inside the support arm body 6. Then, when a compressible fluid, such as air, supplied from the static pressure bearing gas supply device 37 is jetted through each of the jet holes 34a and 35a, the aerostatic bearings 34 and 35 receive (support) the rotor 1 in radial and thrust directions, whereby the entire rotor 1 can be rotatably supported while being floated by a predetermined amount around the mandrel 11.

[0037] When air is jetted to the rotor 1 in the floating state through the pair of jet head portions 9, the rotor 1 is rotated at high speeds. The behavior (vibration condition) at this time is transmitted through the support arm body 6 and the vibration bridge body 4, and then is detected by the various sensors 8 to measure the amount of imbalance of the rotor 1.

[0038] Further, as illustrated in FIGS. 1, 2, and 4 (sectional view along line B-B of Figure 2), of the outer peripheral surface of the mandrel 11, the outer peripheral surface of the pillar portion 32c facing the triangular inner hollow portion 26 (corresponding to the polygon-shaped cross-section portion of the present application) of the rotor 1 includes a vent hole 38. The vent hole 38 comprises a large number of vent holes, that is, here 9 vent holes, which are provided at equal intervals along a circumferential direction of the mandrel 11.

[0039] As illustrated in FIG. 2, any of the vent holes 38 includes a small diameter J-shaped path 39 in which an inlet 39a is opened in a space formed between the pillar portion 32c and the inner surface 26a, and an outlet 39b is opened outside the space. Specifically, the inlet 39a of the path 39 is opened in an outer peripheral surface portion of the pillar portion 32c located near the lowest position in the space between the pillar portion 32c and the inner surface 26a; and the outlet 39b is opened at a position near and facing outside the aerostatic thrust bearing surface 35b, for example, at a position closer to the bearing surface 35b of the end surface of the disk-shaped portion 31 to form the path 39 by the shortest route. The path 39 formed by the shortest route provides a structure in which when the rotor 1 is rotated, a pressure variation occurring in a space between the triangular inner surface 26a and the outer peripheral surface of the pillar portion 32c with a circular cross section, particularly a rising pressure, is relieved outside.

[0040] Next, the relief of the pressure variation will be described.

[0041] First, as illustrated in FIG. 2, when the amount of imbalance of the rotor 1 is measured, the mandrel 11 standing up in the vertical direction is fitted into the support hole 22 of the rotor 1 thereby to mount the rotor 1 on the mandrel 11. As a result, the hole portion 22d of the rotor 1 is disposed on the pillar portion 32a with a circular cross section of the mandrel 11 (including an upper aerostatic radial bearing 34), the stepped portion 22a of the rotor 1 is disposed on the pillar portion 32b (including a lower aerostatic radial bearing 34), and the triangular inner hollow portion 26 of the rotor 1 is disposed on the pillar portion 32c. In addition, the end of the boss portion 21 of the rotor 1 is disposed on the aerostatic thrust bearing surface 35b.

[0042] Then, compressed air (compressible fluid) from the static pressure bearing gas supply device 37 is jetted by a predetermined amount through each of the jet holes 34a and 35a. Then, as illustrated by the arrows in FIG. 2, air jetted through the jet hole 34a flows in between the aerostatic radial bearing surface 34b and the inner surface of the hole portion 22d and the inner surface of the stepped portion 22a, whereby the air flow flowing in therebetween rotatably supports the rotor 1 around the mandrel 11. At the same time, as illustrated by the arrows in FIG. 2, air jetted through the jet hole 35a pushes the boss portion 21 while flowing in between the aerostatic thrust bearing surface 35b and the end surface of the boss portion 21 thereby to float the entire rotor 1 by a predetermined amount. As a result, the mandrel 11 rotatably supports the rotor 1 while floating the rotor 1 by a predetermined amount.

[0043] Then, when air is jetted toward the blades 1a of the floating rotor 1 through the jet holes 9b (only some of them being illustrated in FIG. 1) of the pair of jet head portions 9, the rotor 1 is rotated around the mandrel 11 at high speeds. The behavior (vibration condition) of the rotor 1 at this time is transmitted to the various sensors 8 through the support arm body 6 and the vibration bridge body 4, and then is detected by the various sensors 8 to measure the amount of imbalance of the rotor 1.

[0044] At this time, the space (inner hollow portion 26) between the triangular inner surface 26a of the rotor 1 and the pillar portion 32c of the mandrel 11 is filled with air jetted through the jet holes 34a and 35a of the aerostatic bearings 34 and 35.

[0045] Note that the above described rotor causes no problem because the rotor is mounted on the mandrel with the same circular shape as each other, but the rotor 1 is specified such that the end of the support hole 22 has a polygon shape, specifically, a triangular shape. Therefore, as the rotor 1 is rotated, squeeze occurs between the boss portion 21 having the triangular inner hollow portion 26 and the pillar portion 32c with a circular cross section. For this reason, an increase and a decrease in pressure due to squeeze effect occurs repeatedly in the space between the triangular inner surface 26a and the pillar portion 32c with a circular cross section. Specifically, as illustrated in FIG. 5, pressure is increased on the front side in the direction of the rotation of the varying triangular inner surface 26a, and pressure is decreased on the rear side in the direction of the rotation thereof.

[0046] The rotor 1 generates hunting vibration due to the pressure variation. If left in this state, the rotor 1 is affected by the hunting vibration, which impairs the accuracy of measuring the amount of imbalance of the rotor 1. To avoid this problem, the mandrel 11 includes the vent hole 38 for relieving the pressure varying in the space between the triangular inner surface 26a and the pillar portion 32c with a circular cross section outside. Therefore, as illustrated by the arrows in FIGS. 2 and 5, the pressure variation occurring in the space, that is, the rising pressure, is relieved out of the space (outside) through the vent hole 38. The falling pressure is compensated by the air of the aerostatic bearings 34 and 35.

[0047] This suppresses the pressure variation, as a factor for impairing the accuracy, in the space between the polygonal shaped cross-section portion (triangular inner hollow portion 26) of the support hole 22 and the outer peripheral surface with a circular cross section of the mandrel 11.

[0048] Therefore, the amount of imbalance of the rotor 1 (rotating body) can be measured with a high accuracy. In addition, the measurement accuracy can be improved simply by forming the vent hole 38 at a position of the outer peripheral surface of the mandrel 11 facing the polygon-shaped cross-section portion of the support hole 22, which requires only a simple structure. Further, this structure can avoid a risk, and concern, that the rotor 1 may contact the mandrel 11.

[0049] In particular, a large number of vent holes 38 are provided at equal intervals along a circumferential direction of the mandrel 11, which can evenly relieve the varied pressure outside, thereby further effectively can suppress the pressure variation.

[0050] In addition, the vent holes 38 are formed on the shortest route, which makes it easy to relieve the varied pressure outside, thereby more effectively suppress the pressure variation.

[0051] Note that the present invention is not limited to the above embodiment, and various modifications can be made to the above embodiment without departing from the scope of the present invention. For example, the above embodiment has described an example of using the polygon-shaped portion of the support hole as the triangular inner hollow portion, but without being limited to this, another polygon-shaped inner hollow portion may be used. In addition, the above embodiment has described an example of providing 9 vent holes, but without being limited to this, 9 or more vent holes or 9 or less vent holes may be used as long as the vent holes can sufficiently ensure the effect of suppressing the pressure variation, and thus any number of vent holes may be used. Obviously, the above embodiment has described an example of using the turbocompressor rotor, but without being limited to this, the present invention may be applied to any rotating body as long as the rotating body requires measurement of the amount of imbalance.

Explanation of Reference Signs

[0052]

1	rotor (rotating body)
10	support apparatus (support apparatus for balance correction)
11	mandrel
22	support hole
26	triangular inner hollow portion (polygon-shaped cross-section portion)
26a	triangular inner surface (polygon-shaped inner surface)
34	aerostatic radial bearing
35	aerostatic thrust bearing
38	vent hole
39a	inlet
39b	outlet

Claims

1. A support apparatus for balance correction comprising: a rotating body having a support hole with a circular cross section at a rotation center portion, in which an end side of the support hole is formed in a polygon-shaped cross section, and a vertical mandrel on which the rotating body is mounted in a vertical direction by insertion into the support hole, wherein an outer peripheral surface of the mandrel includes an aerostatic radial bearing rotatably receiving an inner surface with a circular cross section of the support hole, a base end side includes an aerostatic thrust bearing rotatably receiving a periphery of an opening at a lower end of the support hole, and a structure is configured such that compressible fluid for aerostatic bearing is jetted from the aerostatic radial bearing and the aerostatic thrust bearing to rotatably support the rotating body while floating the rotating body around the mandrel, to allow the amount of imbalance to be measured by applying a rotational force to the rotating body in a floating state, wherein
of the outer peripheral surface of the mandrel, an

outer peripheral surface portion facing the polygon-shaped cross-section portion of the support hole includes a vent hole for relieving pressure varying in a space between the polygon-shaped cross-section portion and the outer peripheral surface of the mandrel outside according to rotation of the rotating body.

2. The support apparatus for balance correction according to claim 1, wherein the vent hole comprises a large number of vent holes provided at equal intervals along a circumferential direction on the outer peripheral surface of the mandrel.

3. The support apparatus for balance correction according to claim 1 or 2, wherein the vent hole is a path formed by a shortest route, the path having an inlet near a lowest position in a space between the polygon-shaped cross-section portion of the mandrel and the outer peripheral surface of the mandrel, the path having an outlet at a position facing outside near the aerostatic thrust bearing surface.

FIG. 1

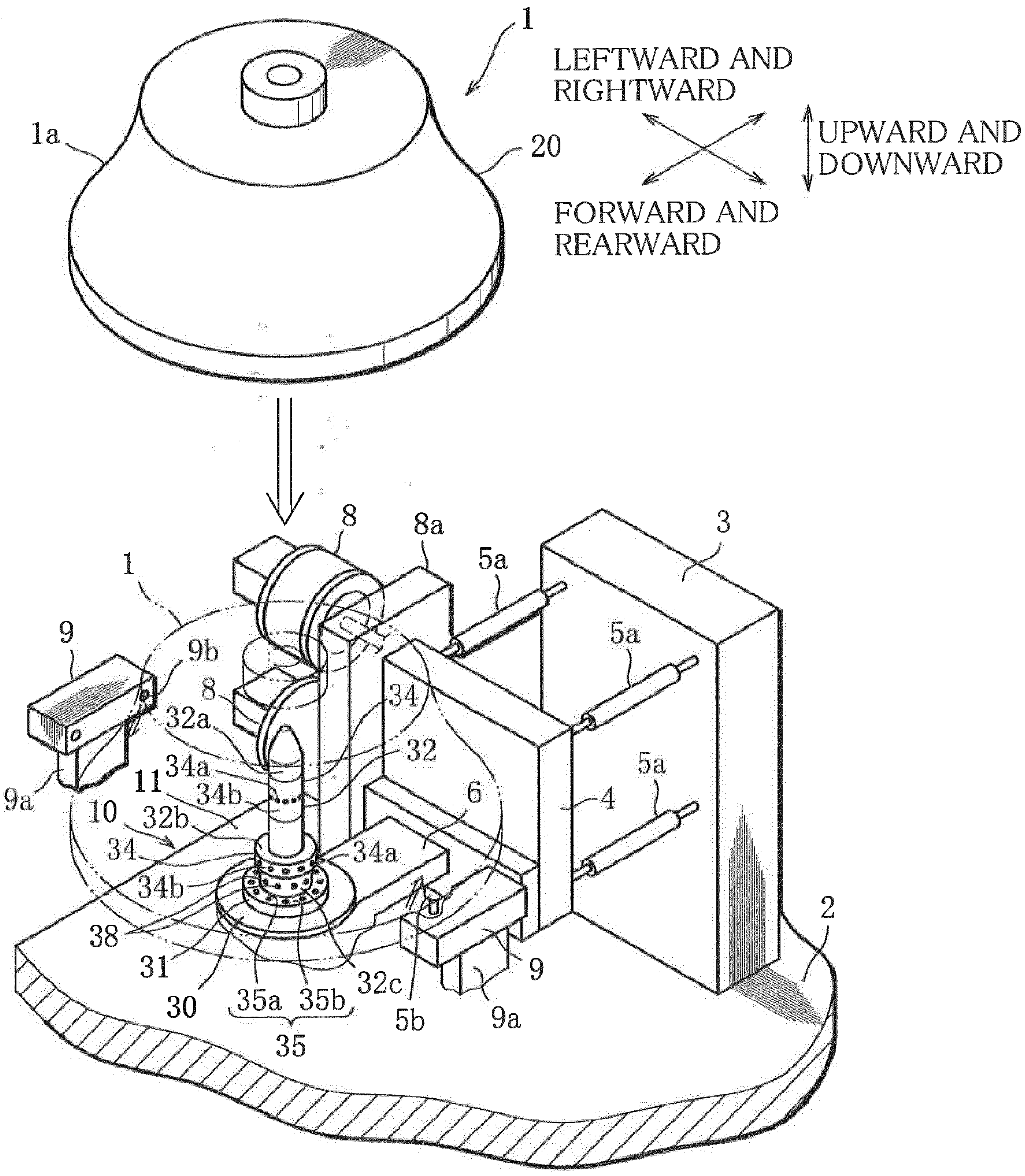
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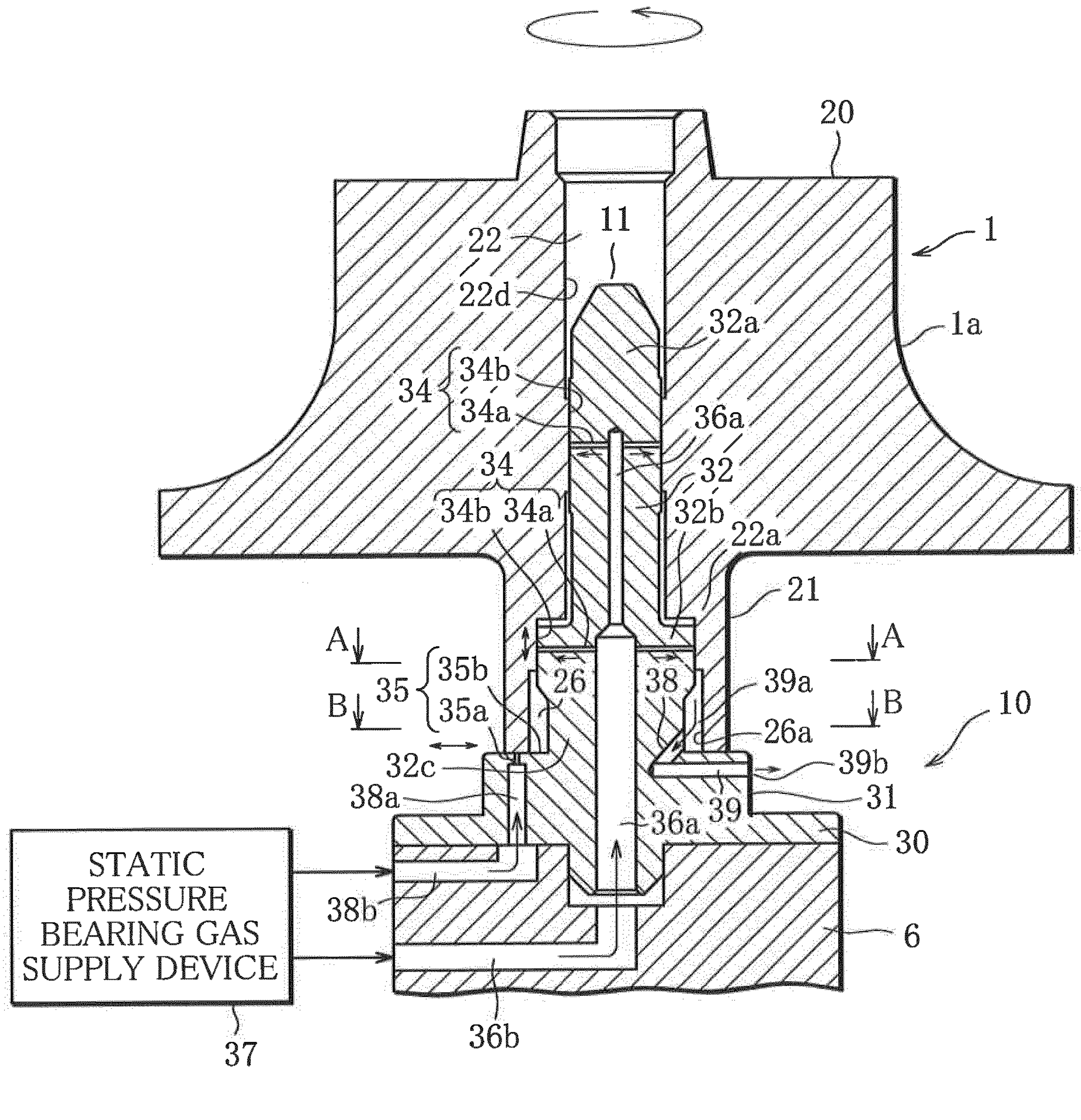
FIG. 2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A
35
35b
35a
26
38
39a
B
B
10
26a
32c
39b
38a
39
31
36a
30
STATIC PRESSURE BEARING GAS SUPPLY DEVICE
38b
6
37
36b

FIG. 3

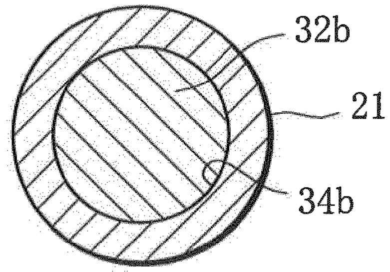


FIG. 4

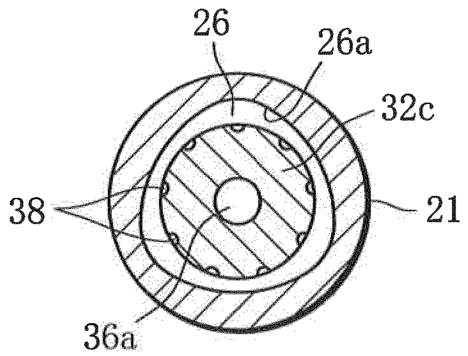


FIG. 5

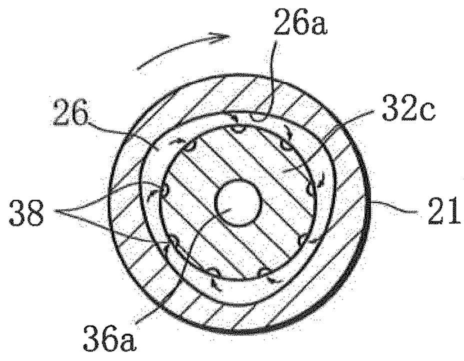


FIG. 6

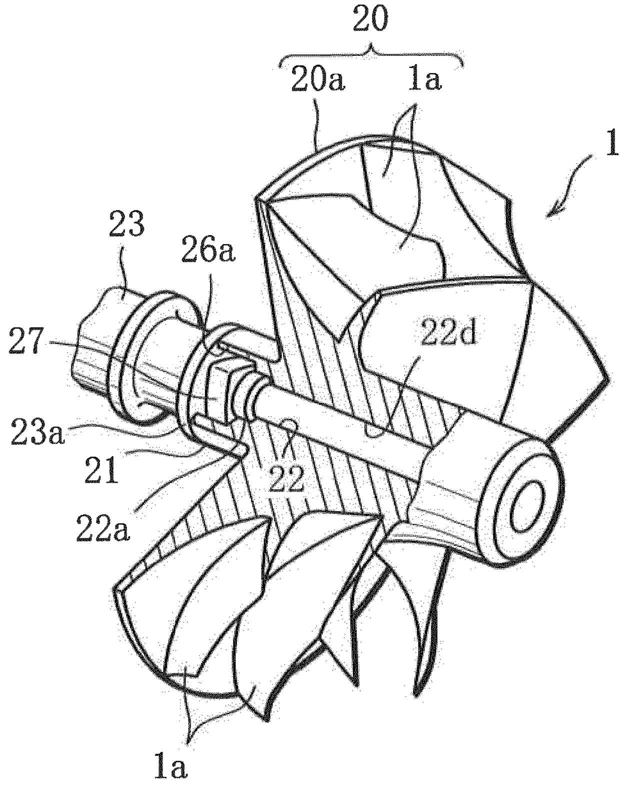
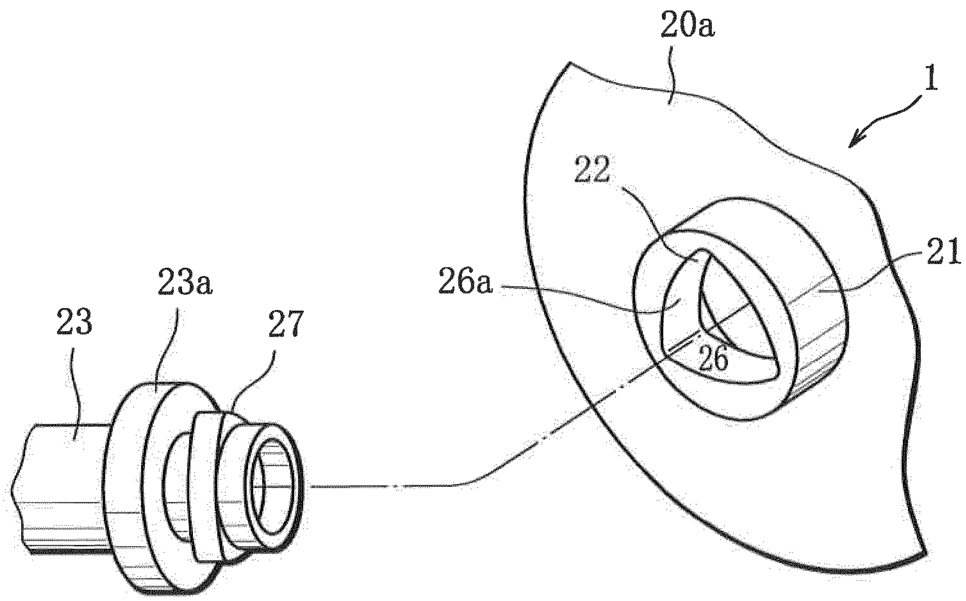


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/073118

A. CLASSIFICATION OF SUBJECT MATTER
G01M1/04(2006.01)i, *G01M1/16*(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)
G01M1/04, G01M1/16

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	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-172538 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 30 June 2005 (30.06.2005), entire text & US 2008/0282782 A1 & EP 1693660 A1 & WO 2005/057156 A1 & KR 10-2006-0118537 A & CN 1894572 A	1-3
A	JP 2006-316951 A (Valeo Thermal Systems Japan Corp.), 24 November 2006 (24.11.2006), entire text (Family: none)	1-3

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

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
13 September, 2013 (13.09.13)	24 September, 2013 (24.09.13)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2005172538 A **[0006]**