US 20140255153A1

(19) **United States**

(12) **Patent Application Publication**

SUMIMOTO

(10) **Pub. No.: US 2014/0255153 A1**

(43) **Pub. Date: Sep. 11, 2014**

(54) **VACUUM PUMP**

(71) Applicant: **Shimadzu Corporation**, Kyoto (JP)

(72) Inventor: **Shin SUMIMOTO**, Kyoto (JP)

(73) Assignee: **Shimadzu Corporation**, Kyoto (JP)

(21) Appl. No.: **14/197,364**

(22) Filed: **Mar. 5, 2014**

(30) **Foreign Application Priority Data**

Mar. 7, 2013 (JP) 2013-045486

Publication Classification

(51) **Int. Cl.**
F04D 19/04 (2006.01)

(52) **U.S. Cl.**
CPC ***F04D 19/042*** (2013.01)
USPC **415/65**

(57) **ABSTRACT**

Each of the stationary blade portions is formed by two or more divided stationary blade portions, and has abutting ends in both circumferential ends, the stationary blade portion is formed by abutting the abutting ends of the divided stationary blade portions with each other. Each of the divided stationary blade portions has an outer circumferential rim nipped by the spacers, an inner circumferential rim positioned in a front end on the inner circumferential side of the stationary blade portion, and a plurality of stator blades formed between the outer circumferential rim and the inner circumferential rim. In abutting ends of the outer circumferential rims where the plurality of divided stationary blade portions is abutted with each other, at least one of the outer circumferential rims has a cutout forming a gap together with the other facing outer circumferential rim.

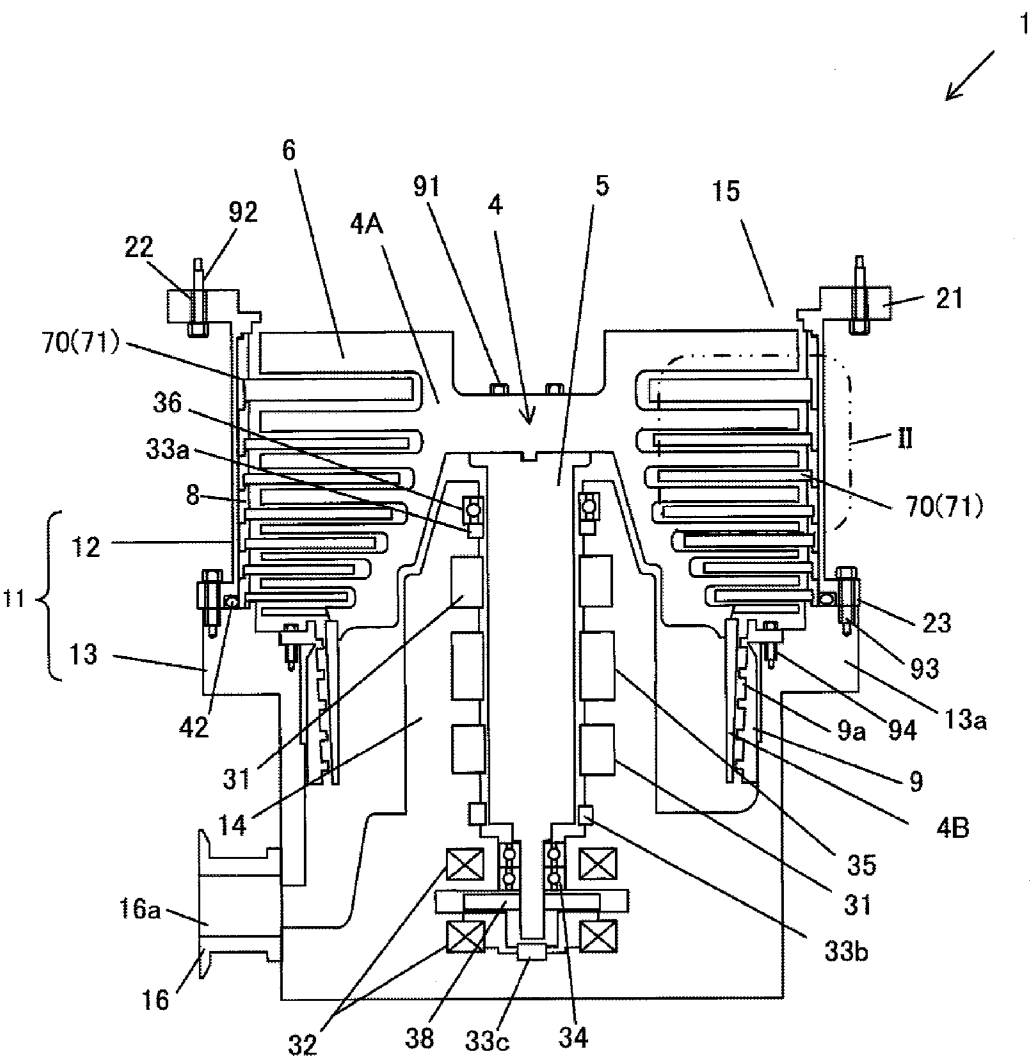


Fig. 1

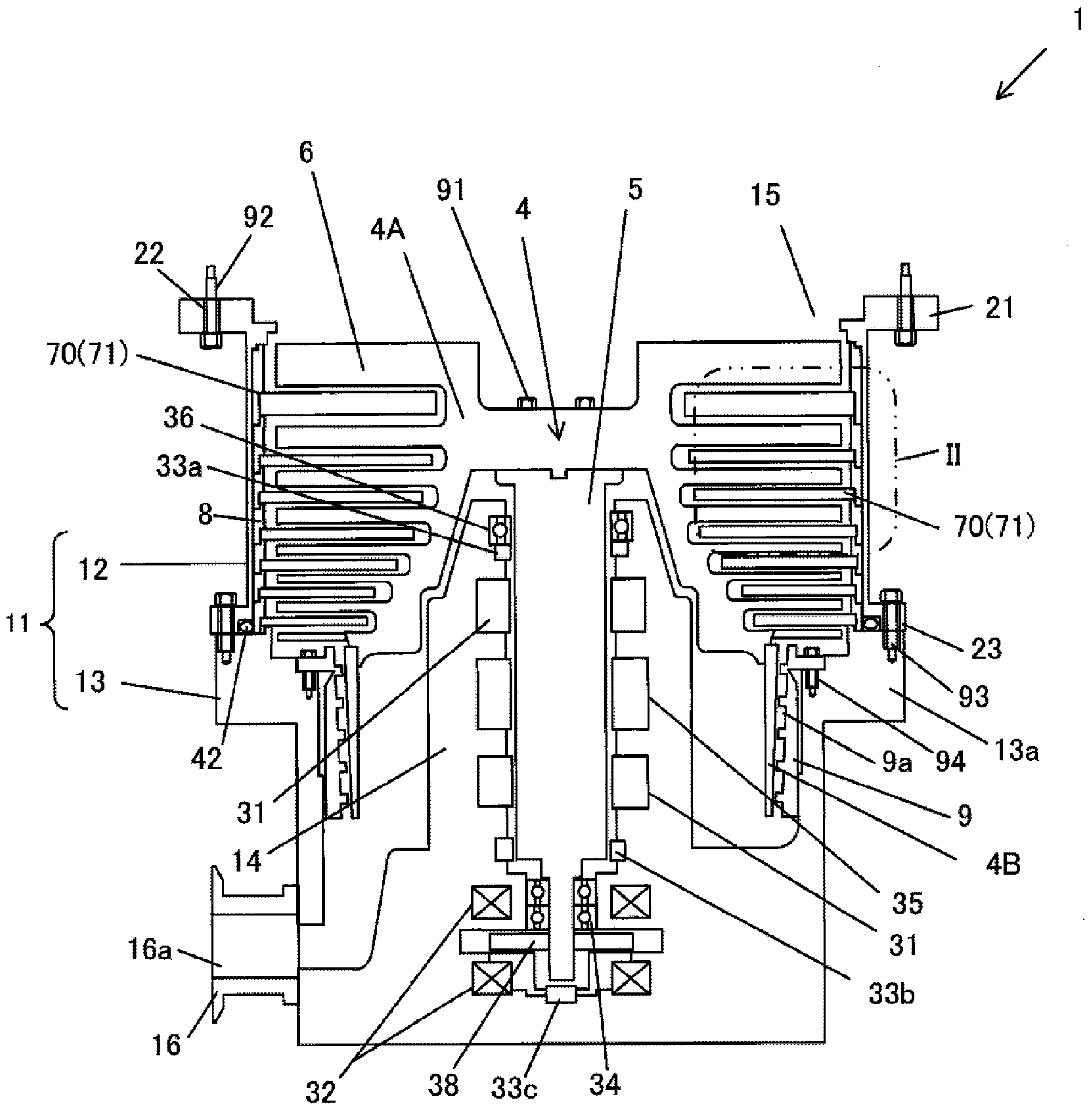

1
6
91
4
5
15
92
4A
22
21
70(71)
36
II
33a
70(71)
8
12
11
13
23
93
42
94
13a
9a
31
9
14
4B
35
31
16a
33b
16
32
38
33c
34

Fig. 2

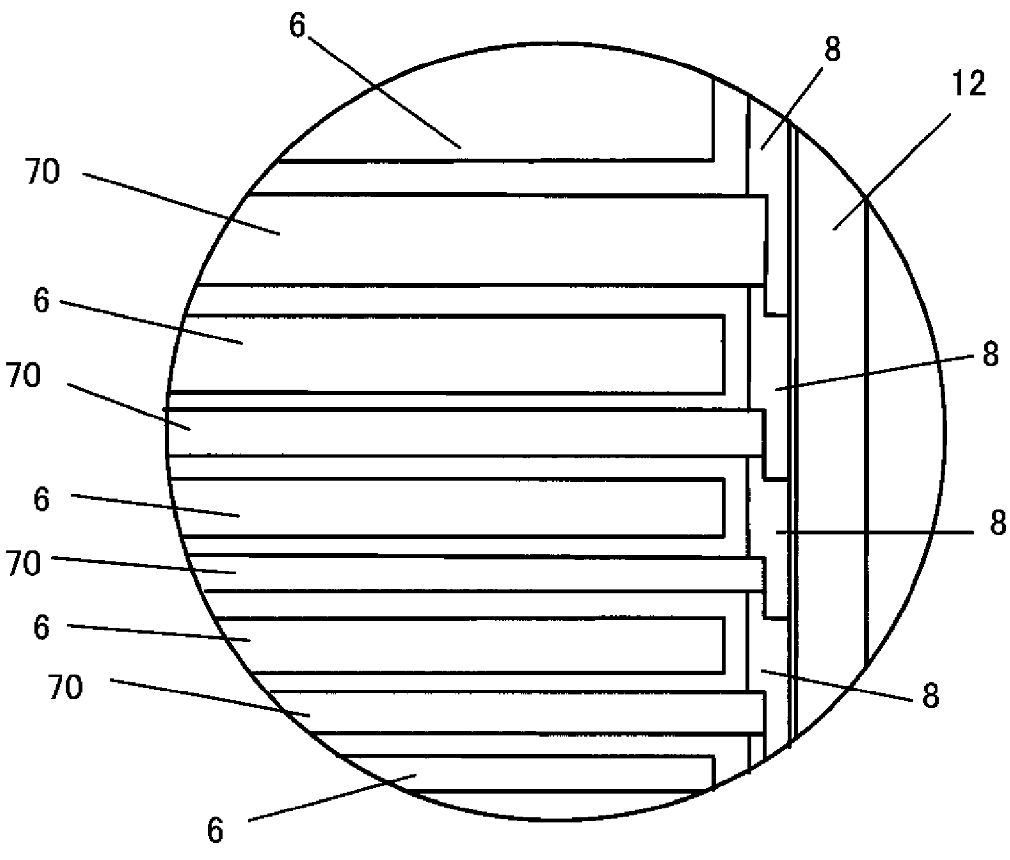


Fig. 3

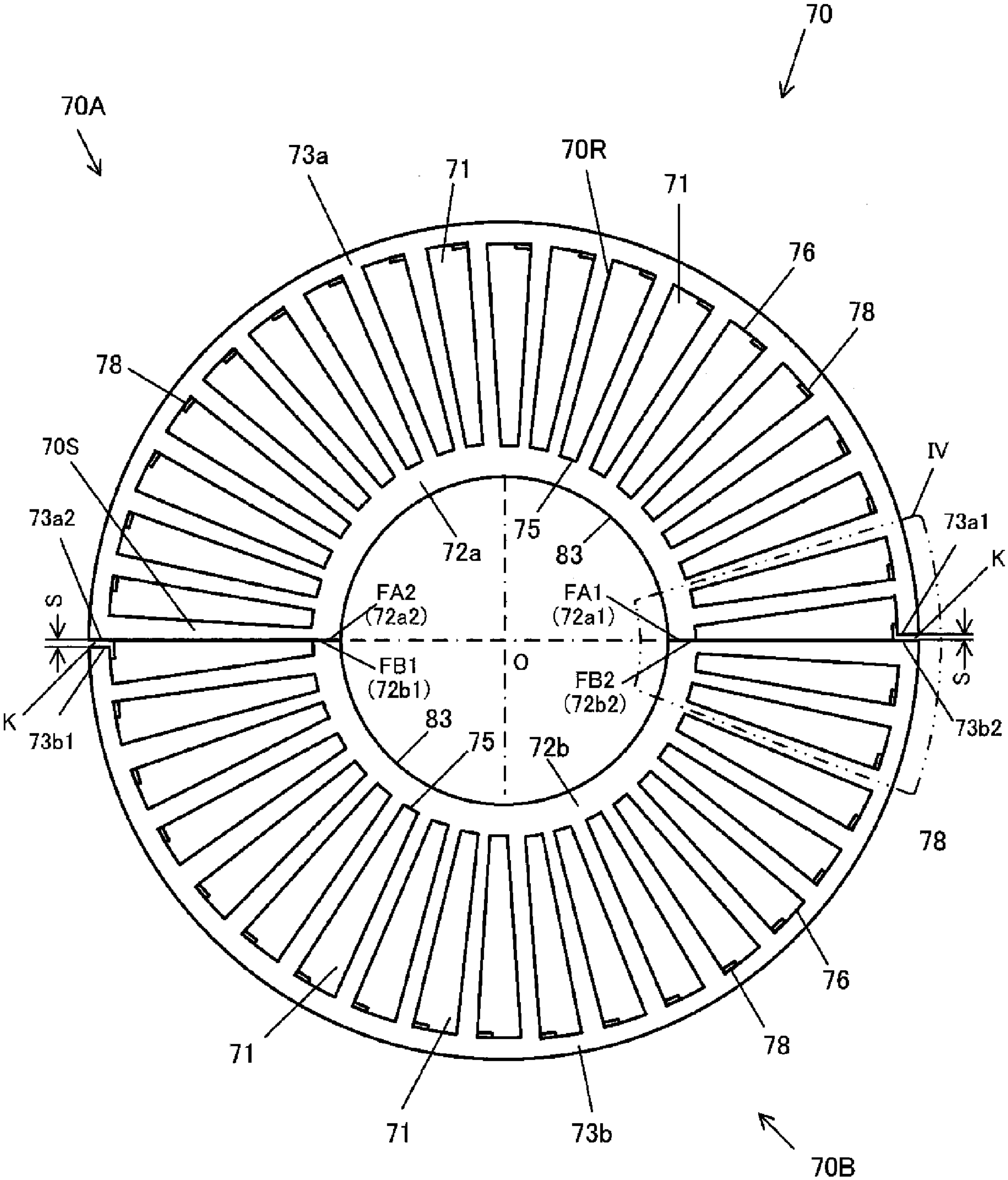
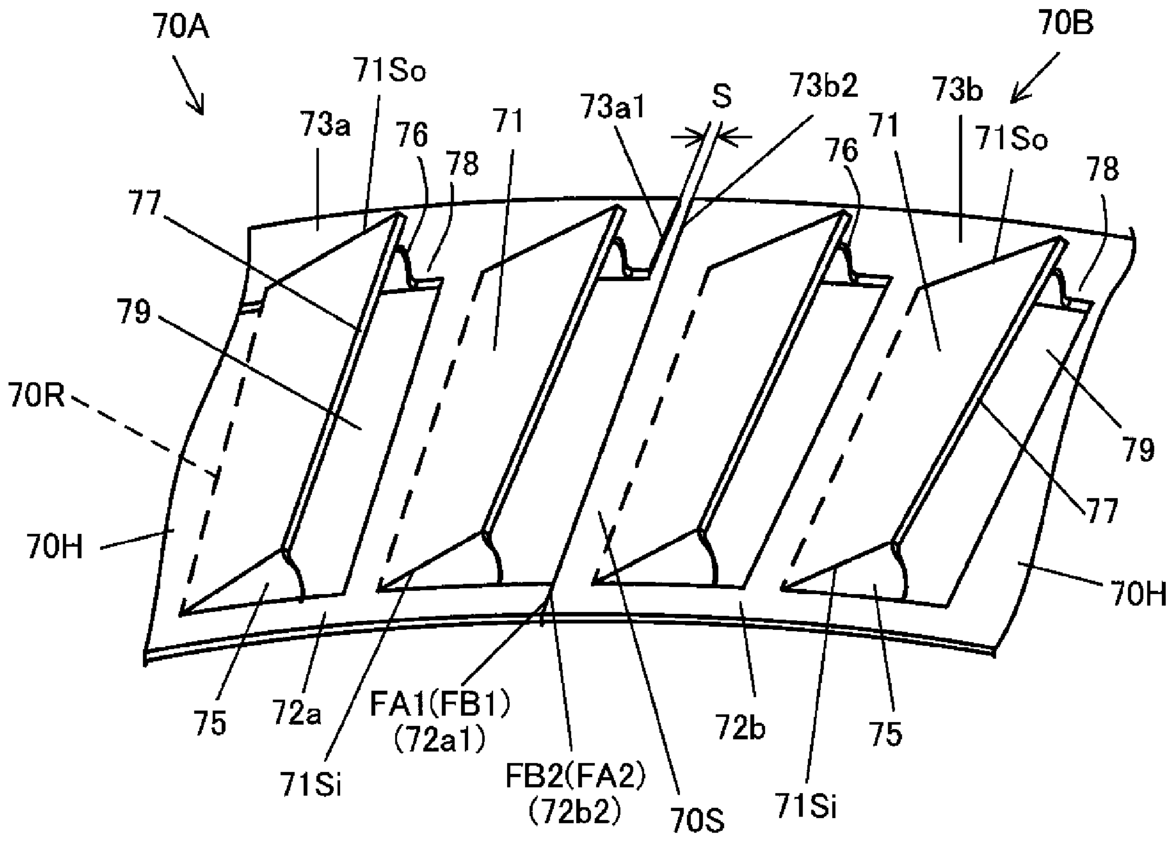

70
70A
73a
71
70R
71
76
78
78
70S
IV
73a2
75
73a1
72a
83
K
FA2
(72a2)
FA1
(72a1)
S
S
FB1
(72b1)
O
FB2
(72b2)
K
73b1
83
73b2
75
72b
78
76
71
78
71
73b
70B

Fig. 4


70A
70B
71So
73a
76
78
71
73a1
S
73b2
73b
71
76
71So
78
77
79
70R
70H
79
77
70H
75
72a
FA1(FB1)
(72a1)
71Si
FB2(FA2)
(72b2)
70S
72b
75
71Si

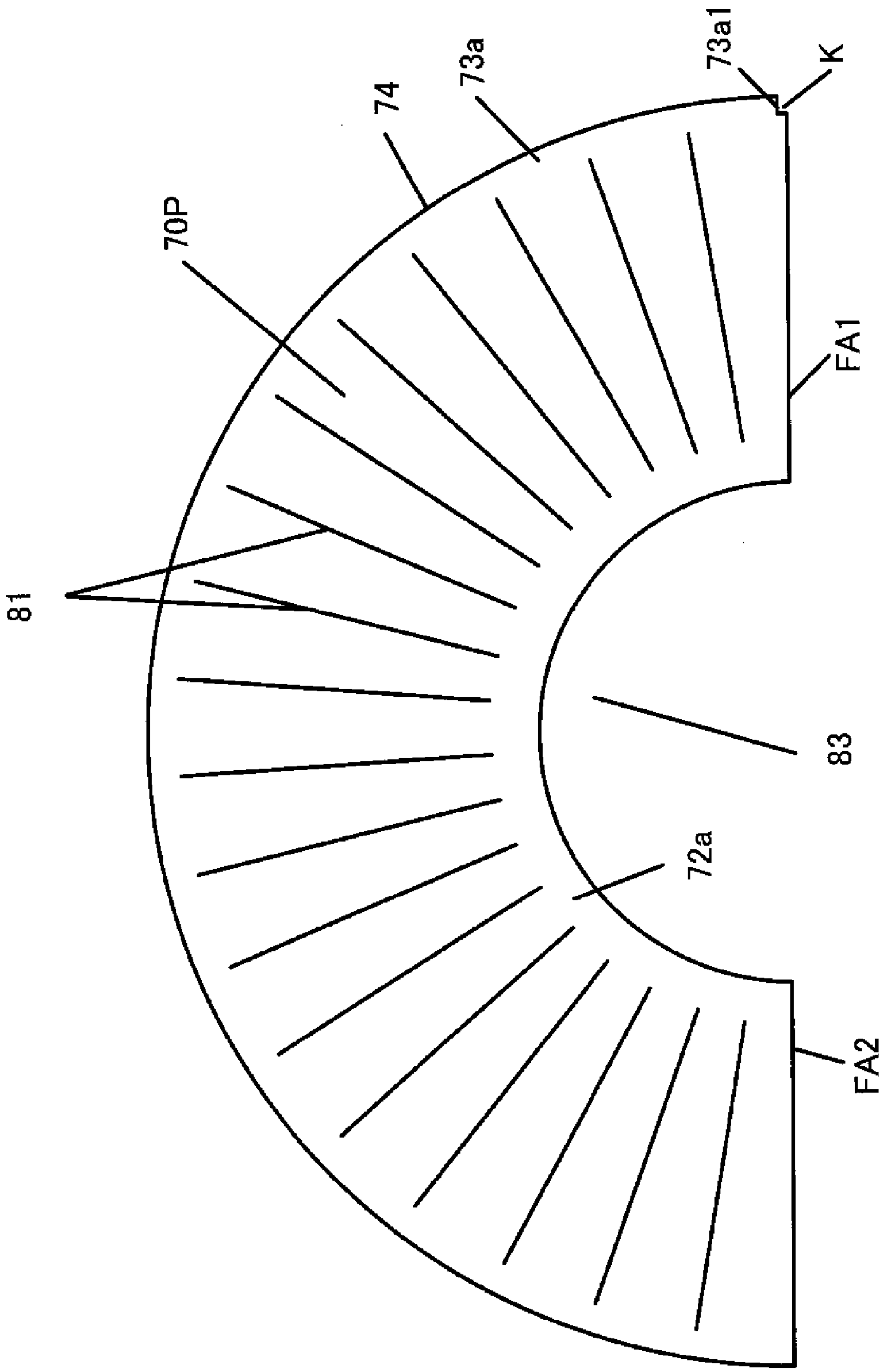


Fig. 5

Fig. 6

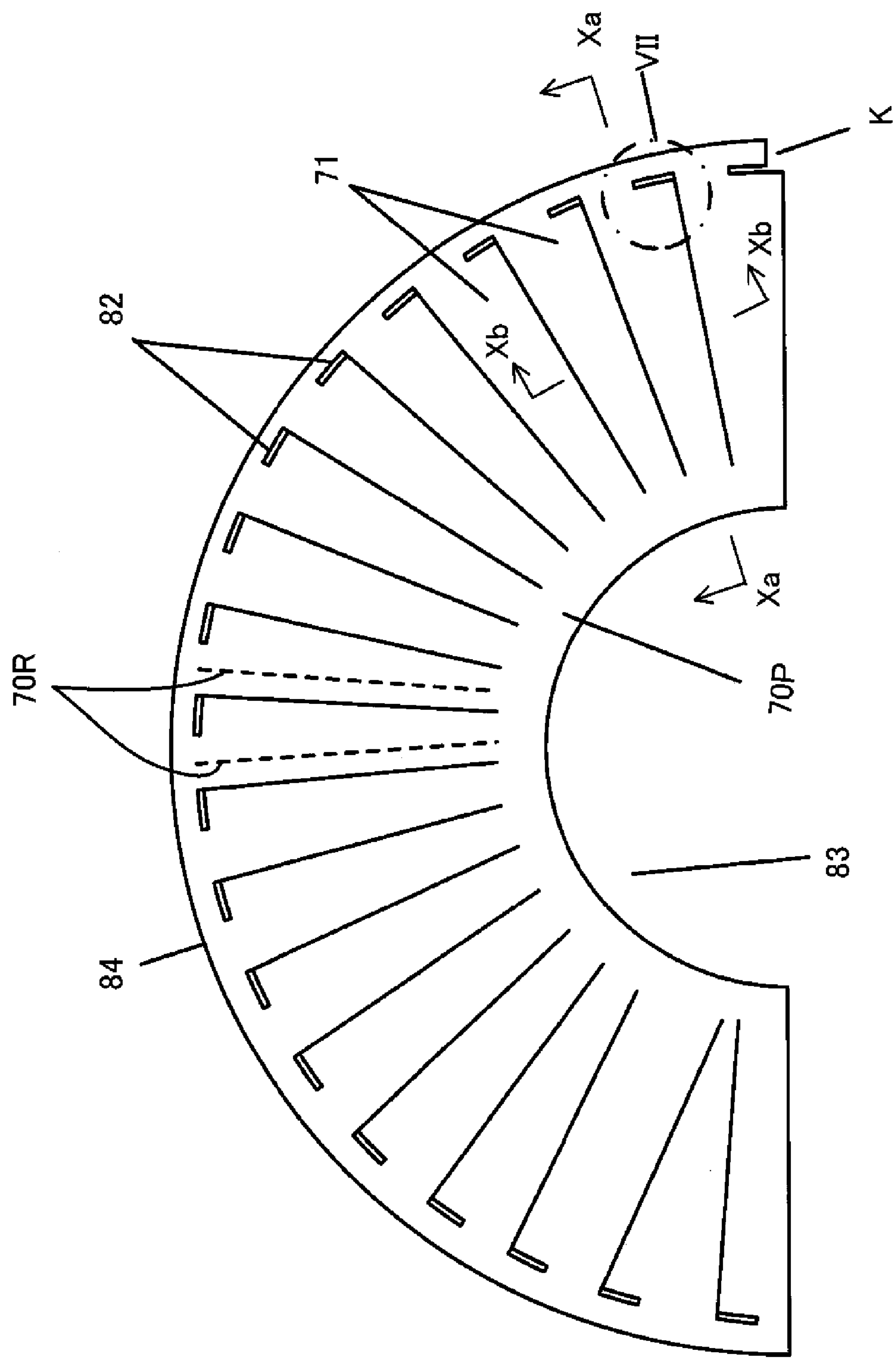


Fig. 7

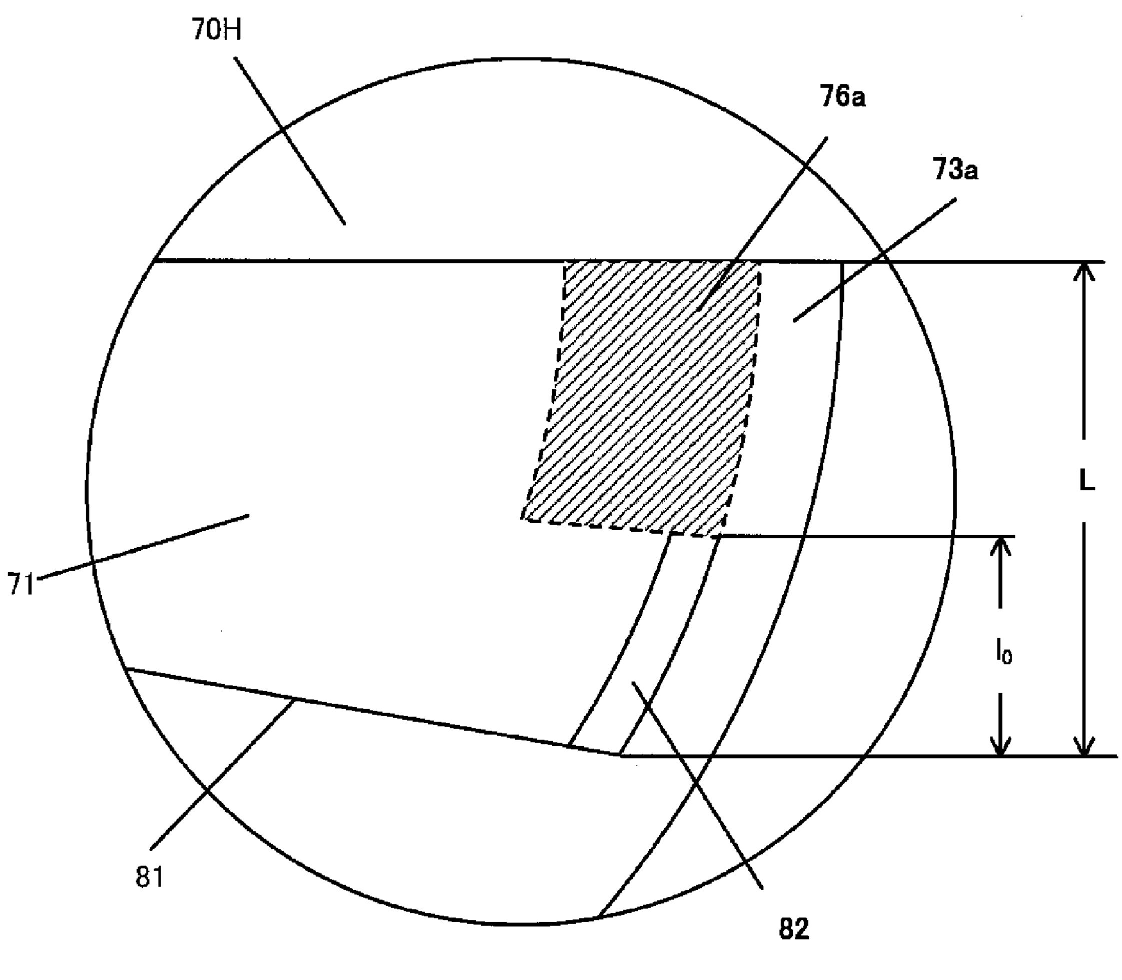


Fig. 8A

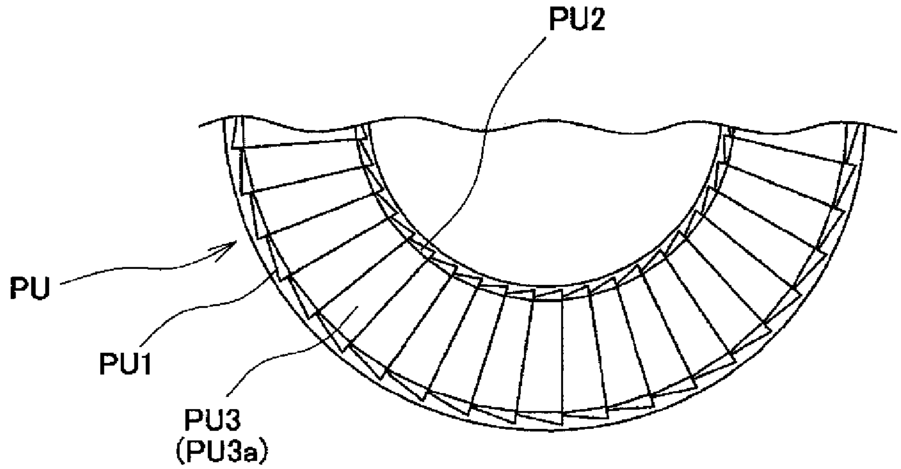


Fig. 8B

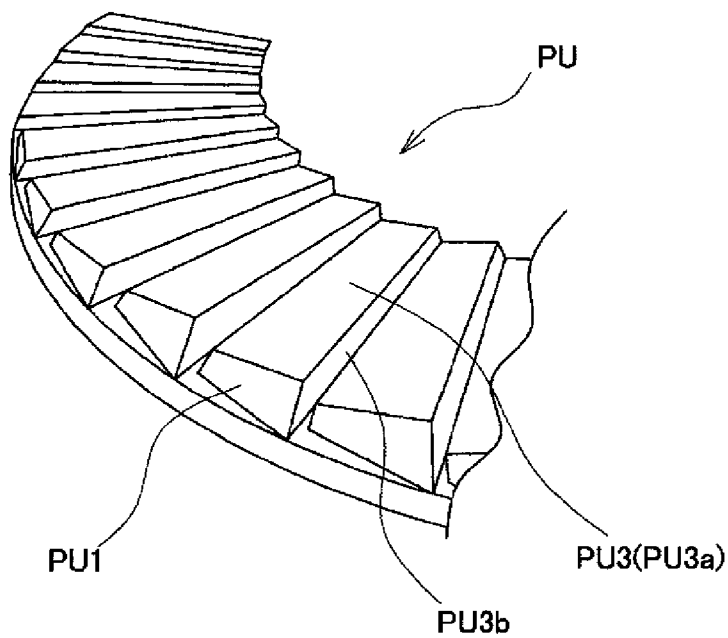


Fig. 9A

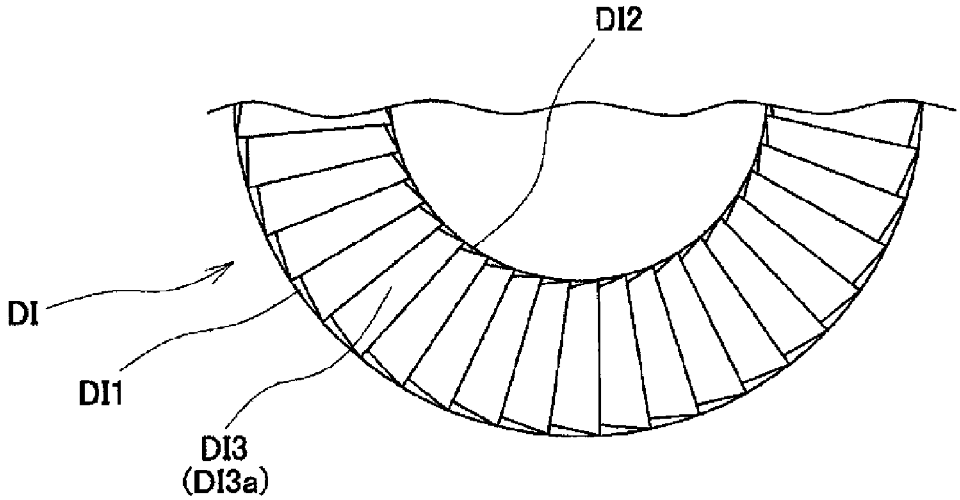


Fig. 9B

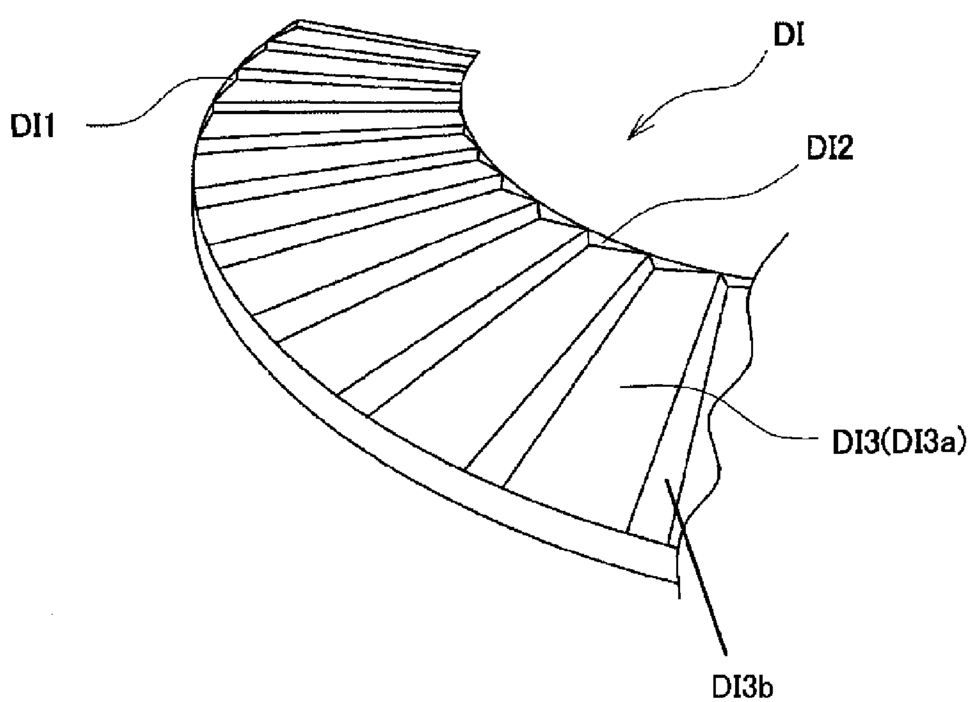


Fig. 10A

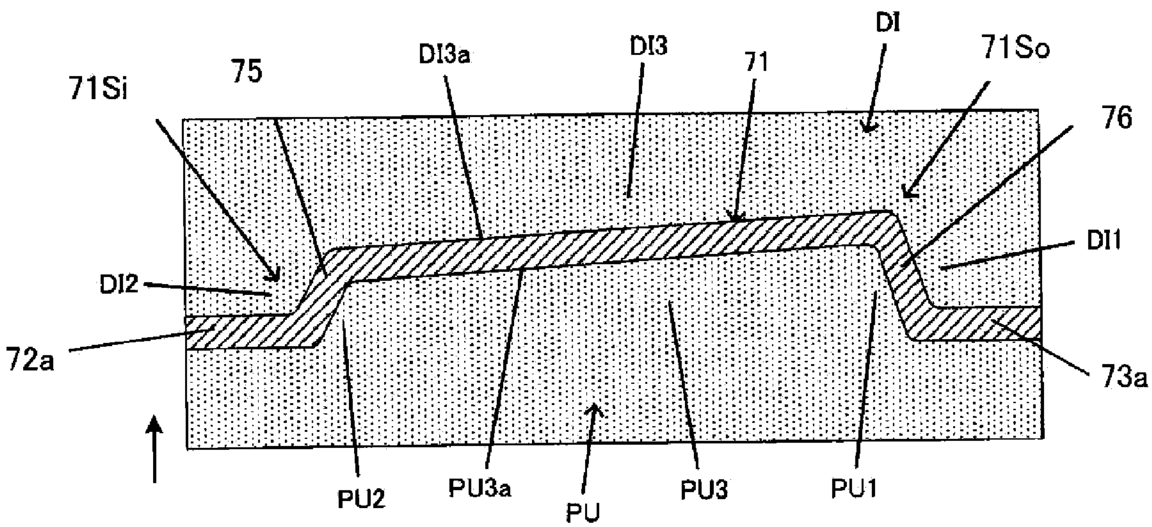


Fig. 10B

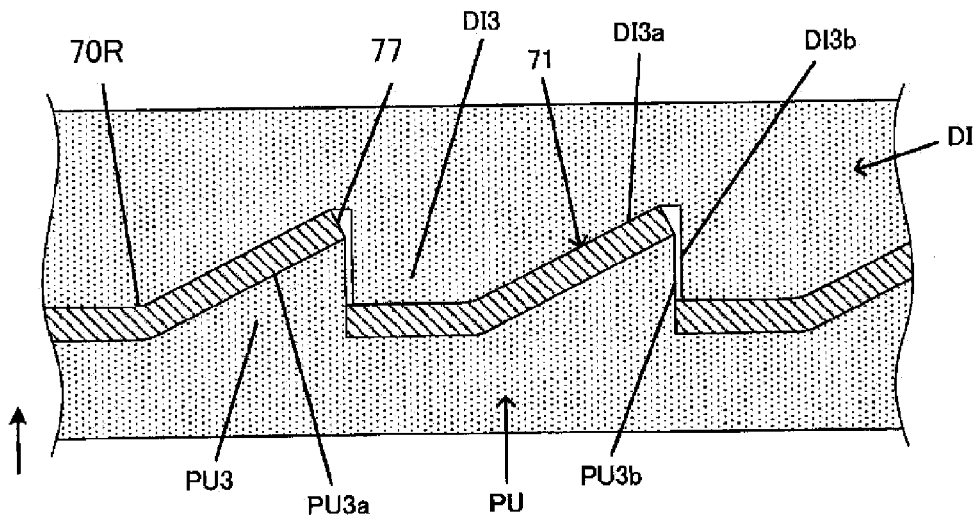


Fig. 11

Embodiment 2

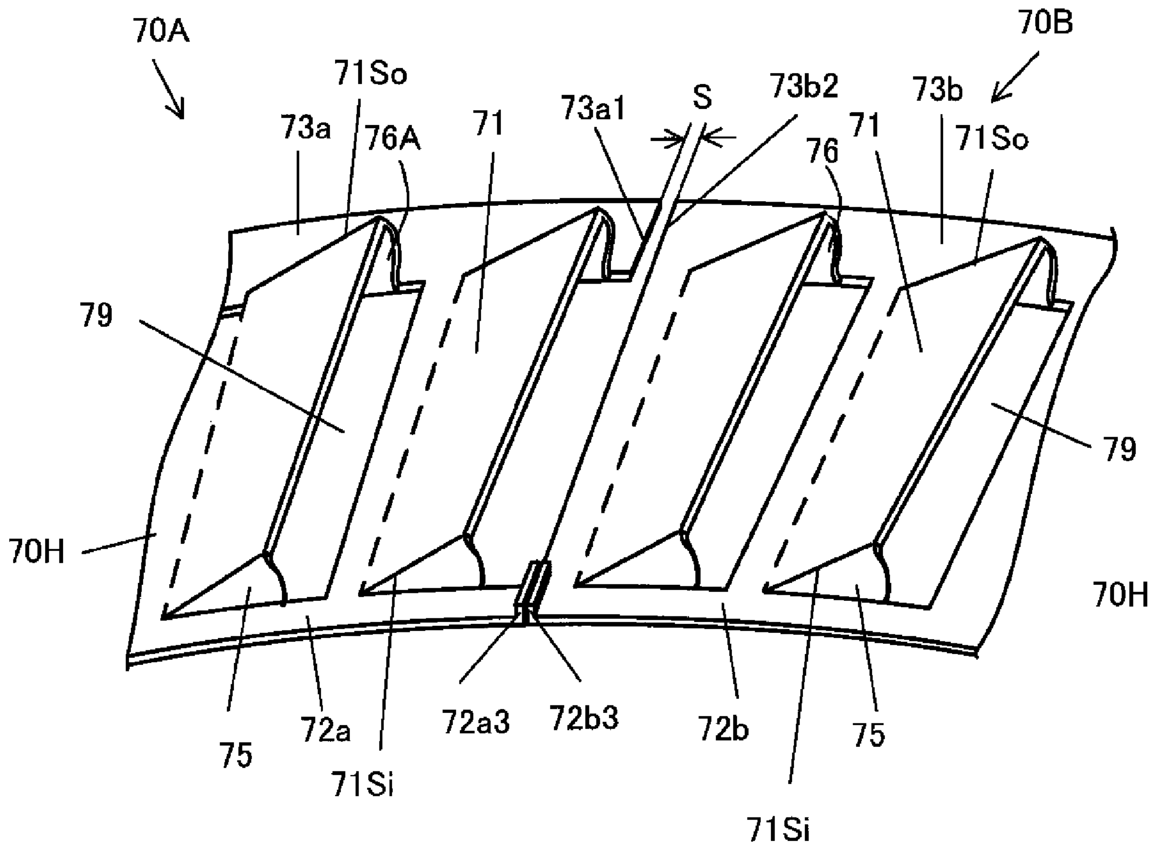
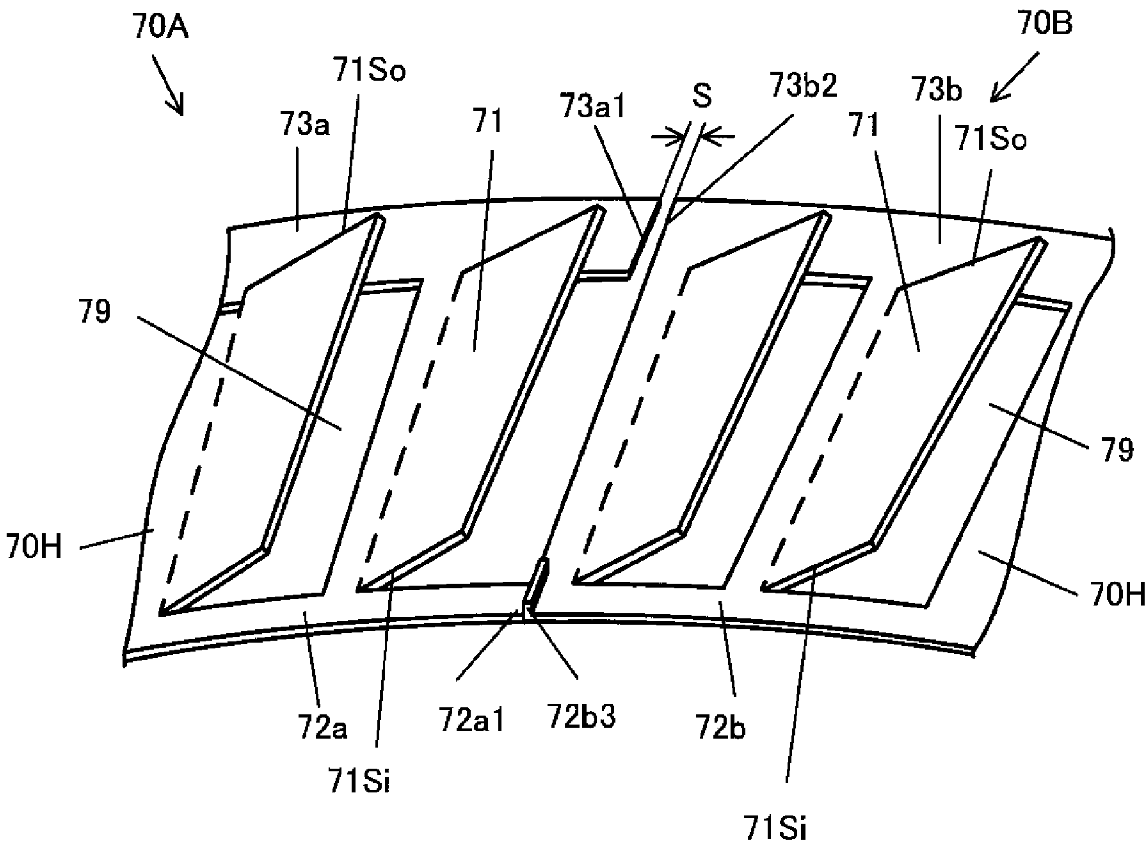


Fig. 12

Embodiment 3



VACUUM PUMP

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a vacuum pump having an exhaust portion formed by rotating blade portions and stationary blade portions.

[0003] 2. Description of the Related Art

[0004] In a vacuum pump such as a turbo-molecular pump, a rotor having rotating blade portions arranged in multiple stages is rotated at high speed in a pump container, and a gas molecule is moved from the intake port side to the exhaust port side by the rotating blade portions and stationary blade portions arranged between the stages of the rotating blade portions.

[0005] Each stage of the rotating blade portions has rotor blades, and each stage of the stationary blade portions has stator blades. The stationary blade portions are supported at predetermined intervals by spacers arranged on outer circumferences of the stationary blade portions. The stationary blade portions are formed into one ring shape by combining a pair of halved ring shape members. That is, one ring is formed by abutting two abutting ends each other serving as abutting portions of the halved ring shape members. The rotor blades and the stator blades are formed so as to be inclined with respect to a rotation surface of the rotor.

[0006] As a method of manufacturing the stationary blade portions, there are a method of forming by mechanical working and a method of forming by plastic working. The method of manufacturing by the plastic working is advantageous in terms of cost.

[0007] In the method of forming by the plastic working, a plurality of stator blades formed by pressing a plate and arranged at a predetermined inclination angle along the circumferential direction is coupled by an inner circumferential rim and an outer circumferential rim, so that a stationary blade portion is manufactured. Due to variation at the time of the working, there is sometimes a case where a circumferential length of the halved ring shape members is longer than designed size. Therefore, when one ring is formed by abutting the abutting ends of the halved ring shape members with each other, the abutting ends of the halved ring shape members are overlapped with each other or the abutting ends are warped by reactive force of the abutting ends against each other.

[0008] Conventionally, there is a known structure that slits are provided on an abutting surface of an inner circumferential rim in a state where the halved ring shape members are abutted with each other (for example, refer to JP 2006-77713 A).

[0009] As described above, when the circumferential length of the halved ring shape members is varied at the time of the working, overlap and warpage are generated in the stationary blade portion. Japanese Unexamined Patent Application Publication No. 2006-77713 describes neither such a problem nor a measure against this.

SUMMARY OF THE INVENTION

[0010] A vacuum pump has an exhaust function portion in which stationary blade portions nipped by spacers are respectively arranged between rotating blade portions arranged in multiple stages. Each of the stationary blade portions is formed by two or more divided stationary blade portions, each of the divided stationary blade portions has abutting ends in both circumferential ends, the stationary blade portion is formed by abutting the abutting ends of the divided stationary blade portions with each other, each of the divided stationary blade portions has an outer circumferential rim nipped by the spacers, an inner circumferential rim positioned in a front end on the inner circumferential side of the stationary blade portion, and a plurality of stator blades formed between the outer circumferential rim and the inner circumferential rim, and in abutting ends of the outer circumferential rims where the plurality of divided stationary blade portions is abutted with each other, at least one of the outer circumferential rims has a cutout forming a gap together with the other facing outer circumferential rim.

[0011] According to this invention, even in a case where a circumferential length between abutting ends is formed to be longer than designed size due to size variation at the time of working of divided stationary blade portions, at the time of assembling a stationary blade portion, ends of outer circumferential rims of a plurality of divided stationary blade portions can be suppressed from being overlapped with each other, or generation of warpage can be suppressed in the divided stationary blade portions themselves, namely the stationary blade portion itself.

[0012] Preferably, each of the divided stationary blade portions is manufactured from a flat plate into the same shape, an abutting end surface of the inner circumferential rim and an abutting end surface of the outer circumferential rim are formed as a first abutting surface in the one abutting end of the divided stationary blade portion, an end surface of the inner circumferential rim, an end surface of the outer circumferential rim, and an end surface of an edge member forming an opening portion are formed as a second abutting surface in the other abutting end, and the first abutting surface and the second abutting surface are abutted with each other so as to form the stationary blade portion.

[0013] Preferably, the cutout is provided in the outer circumferential rim as a rectangular shape with a predetermined width in the circumferential direction and a predetermined length in a radial direction.

[0014] Preferably, a bending portion bent from the inner circumferential rim is provided in at least one of end surfaces of the inner circumferential rims where the plurality of divided stationary blade portions is abutted with each other.

[0015] Preferably, the gap is determined based on maximum tolerance α of circumferential length between both the abutting ends, and/or maximum tolerance β between an outer circumferential surface of the stationary blade portion assembled from the divided stationary blade portions and an inner circumferential surface of the spacer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a sectional view of a turbo-molecular pump serving as one embodiment of a vacuum pump according to this invention;

[0017] FIG. **2** is an enlarged view of a region II in FIG. **1**;

[0018] FIG. **3** is a plan view of a stationary blade portion;

[0019] FIG. **4** is an enlarged perspective view of a region IV in FIG. **3**;

[0020] FIG. **5** is a plan view of a half-disc plate for illustrating a manufacturing method of the stationary blade portion;

[0021] FIG. **6** is a plan view of the half-disc plate for illustrating a step following FIG. **5**;

[0022] FIG. **7** is an enlarged view of a region VII in FIG. **6**;

[0023] FIG. **8**A is a plan view of a punch, and FIG. **8**B is a perspective view of the punch;

[0024] FIG. **9**A is a plan view of a die, and FIG. **9**B is a perspective view of the die;

[0025] FIG. **10** is views for illustrating a method of manufacturing a stator blade by drawing with using a punch PU and a die DI, FIG. **10**A is a sectional view taken along line Xa-Xa in FIG. **6** at the time of the drawing, and FIG. **10**B is a sectional view taken along line Xb-Xb in FIG. **6** at the time of the drawing;

[0026] FIG. **11** is an enlarged perspective view of Embodiment 2 in major parts of the stationary blade portion of the present invention; and

[0027] FIG. **12** is an enlarged perspective view of Embodiment 3 in the major parts of the stationary blade portion of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Embodiment 1

[0028] Hereinafter, referring to the drawings, a vacuum pump according to the present invention will be described with a turbo-molecular pump as one embodiment.

(Entire Configuration of Vacuum Pump)

[0029] FIG. **1** is a sectional view of a turbo-molecular pump **1**, and FIG. **2** is an enlarged view of a region II in FIG. **1**.

[0030] The turbo-molecular pump **1** includes a pump container **11** formed by a casing member **12** and a base **13** fixed to the casing member **12**.

[0031] The casing member **12** has a substantially cylindrical shape, and formed by for example SUS, and an upper flange **21** is formed in an upper end. A disc shape intake port **15** is formed on the inner side of the upper flange **21** of the casing member **12**. Through holes **22** for bolt insertion are formed in the upper flange **21** at substantially equal intervals along the circumferential direction. The turbo-molecular pump **1** is attached to an external device such as semiconductor manufacturing device by inserting bolts **92** into the through holes **22** of the upper flange **21**.

[0032] A rotor **4** and a rotor shaft **5** attached coaxially with an axis of the rotor **4** are accommodated in the pump container **11**. The rotor **4** and the rotor shaft **5** are fixed by bolts **91**.

[0033] The rotor **4** includes a rotor upper portion **4**A, and a rotor lower portion cylindrical portion **4**B jointed to a lower surface of the rotor upper portion **4**A. The rotor upper portion **4**A is made of for example an aluminum alloy. In the rotor upper portion **4**A, a plurality of rotating blade portions **6** formed in a radial manner and arranged in the circumferential direction is arranged in multiple stages at intervals in the axial direction of the rotor **4**. The rotating blade portions **6** are formed at a predetermined inclination angle with respect to a rotation surface of the rotating blade portions **6**.

[0034] As shown in FIG. **2**, stationary blade portions **70** having stator blades **71** (refer to FIG. **3**) are arranged between the stages of the plurality of rotating blade portions **6**.

[0035] The stationary blade portions **70** are formed into one ring shape by combining a pair of halved ring shape members. Each of the stationary blade portions **70** is nipped by ring-shaped spacers **8** arranged along an inner circumferential surface of the casing member **12**, and the stationary blade portions are laminated in multiple stages (seven stages in the example shown in the figure). An upper surface of the uppermost spacer **8** is abutted with an inner surface of the upper flange **21** of the casing member **12**, and a lower surface of the lowermost spacer **8** is abutted with an upper surface of an upper flange **13***a* of the base **13**. Therefore, the stationary blade portions **70** are given force in the rotation shaft direction and supported via the spacers **8** between the inner surface of the upper flange **21** of the casing member **12** and the upper surface of the upper flange **13***a* of the base **13**. In such a way, the rotating blade portions **6** and the stationary blade portions **70** are alternately laminated in multiple stages, so as to form a high-vacuum blade exhaust portion.

[0036] A ring shape threaded stator **9** is fixed to the base **13** by bolts **94** at the outer circumferential side of the rotor lower portion cylindrical portion **4**B. A threaded groove portion **9***a* is formed in the threaded stator **9**. A low-vacuum threaded groove exhaust portion is formed by the rotor lower portion cylindrical portion **4**B of the rotor **4** and the threaded stator **9**.

[0037] It should be noted that although the structure of forming the threaded groove portion **9***a* in the threaded stator **9** is shown as an example in FIG. **1**, the threaded groove portion **9***a* may be formed on an outer circumferential surface of the rotor lower portion cylindrical portion **4**B.

[0038] The base **13** is made of for example an aluminum alloy, and a center tube portion **14** in which a disc shape hollow part is formed for inserting the rotor shaft **5** is formed in a center part of the base **13**. On the inner side of the center tube portion **14**, a motor **35**, (two) radial magnetic bearings **31**, (a pair of upper and lower) thrust magnetic bearings **32**, radial displacement sensors **33***a*, **33***b*, an axial displacement sensor **33***c*, mechanical bearings **34**, **36**, and a rotor disc **38** are attached.

[0039] The rotor shaft **5** is supported by the (two) radial magnetic bearings **31** and the (pair of upper and lower) thrust magnetic bearings **32** in non-contact manner. A position of the rotor shaft **5** at the time of rotation is controlled based on a radial position and an axial position detected by the radial displacement sensors **33***a*, **33***b* and the axial displacement sensor **33***c*. The rotor shaft **5** rotatably and magnetically floated up by the magnetic bearings **31**, **32** is driven and rotated at high speed by the motor **35**. By driving and rotating the rotor shaft **5**, the rotor upper portion **4**A coupled to the rotor shaft **5** is rotated and all the rotating blade portions **6** are integrally rotated.

[0040] The mechanical bearings **34**, **36** are mechanical bearings for emergency, and when the magnetic bearings **31**, **32** are not operated, the rotor shaft **5** is supported by the mechanical bearings **34**, **36**.

[0041] An exhaust port **16** is provided in the base **13**, and an exhaust opening **16***a* is provided in the exhaust port **16**.

[0042] A lower flange **23** of the casing member **12** and the upper flange **13***a* of the base **13** are fixed by bolts **93** through a seal member **42**, so that the pump container **11** is formed.

[0043] As described above, the vacuum pump of the embodiment is a vacuum pump having an exhaust function portion in which the stationary blade portions **70** supported by the spacers **8** are respectively arranged between the rotating blade portions **6** arranged in multiple stages.

[0044] Hereinafter, the stationary blade portions **70** will be described in detail.

(Description of Stationary Blade Portion **70**)

[0045] FIG. **3** is a plan view of the stationary blade portion **70** shown in FIG. **1**, and FIG. **4** is an enlarged perspective view of a region IV in FIG. **3**.

[0046] The stationary blade portion **70** is formed by combining two divided stationary blade portions **70**A, **70**B serving as the halved ring shape members. The divided stationary blade portions **70**A, **70**B are formed into the same shape. Each of the divided stationary blade portions **70**A, **70**B has an opening **83** in a center part, and serves as a half annular body in a plan view (hereinafter, also referred to as a half-disc shape for convenience). Each of the divided stationary blade portions **70**A, **70**B includes an outer circumferential rim **73***a*, an inner circumferential rim **72***a*, and the plurality of stator blades **71** extended in a radial manner with predetermined width in the circumferential direction between the outer circumferential rim **73***a* and the inner circumferential rim **72***a*.

[0047] As described later, the divided stationary blade portion **70**A has abutting ends FA**1** and FA**2**, and the divided stationary blade portion **70**B has abutting ends FB**1** and FB**2**. Both the circumferential ends of the divided stationary blade portions **70**A, **70**B are respectively formed into different shapes. Referring to FIG. **4**, in the one circumferential end FA**1** of the divided stationary blade portion **70**A, an exhaust opening **79** exists between the inner circumferential rim **72***a* and the outer circumferential rim **73***a* and the circumferential rims are separated from each other. Meanwhile, in the other circumferential end FA**2** of the divided stationary blade portion **70**A, the inner circumferential rim **72***a* and the outer circumferential rim **73***a* are connected by a bridge **70**S forming the exhaust opening **79**.

[0048] A cutout K is provided in one end **73***a***1** of the outer circumferential rim **73***a* of the divided stationary blade portion **70**A and one end **73***b***1** of an outer circumferential rim **73***b* of the divided stationary blade portion **70**B. The cutout K is formed so as to separate the abutting end FA**1** and the abutting end FB**2** or to separate the abutting end FB**1** and the abutting end FA**2**.

[0049] The one abutting end FA**1** of the divided stationary blade portion **70**A and the other abutting end FB**2** of the divided stationary blade portion **70**B are abutted with each other, and the other abutting end FA**2** of the divided stationary blade portion **70**A and the one abutting end FB**1** of the divided stationary blade portion **70**B are abutted with each other. In other words, one end **72***a***1** of the inner circumferential rim **72***a* of the divided stationary blade portion **70**A and the other end **72***b***2** of an inner circumferential rim **72***b* of the divided stationary blade portion **70**B are abutted with each other, and the other end **72***a***2** of the inner circumferential rim **72***a* of the divided stationary blade portion **70**A and one end **72***b***1** of the inner circumferential rim **72***b* of the divided stationary blade portion **70**B are abutted with each other.

(Description of Cutout K)

[0050] In a case where the divided stationary blade portions are manufactured as designed values, a straight line connecting an abutting surface between the abutting end FA**1** and the abutting end FB**2** and an abutting surface between the abutting end FA**2** and the abutting end FB**1** passes through center O of a true circle formed by the divided stationary blade portions **70**A and **70**B. However, at the time of manufacturing the divided stationary blade portions **70**A, **70**B by plastic working, the divided stationary blade portions **70**A, **70**B may sometimes be formed in such a manner that a circumferential length between the abutting ends FA**1** and FA**2** or between the abutting ends FB**1** and FB**2** is longer than designed size. In this case, there is a fear that both the divided stationary blade portions **70**A, **70**B are overlapped with each other in the abutting ends or the stationary blade portion **70** itself is warped by reactive force of both the abutting ends against each other.

[0051] In this embodiment, the cutout K shown in FIGS. **5**, **6** is provided in the one abutting end FA**1** of the divided stationary blade portion **70**A and the cutout K is provided in the one abutting end FB**1** of the divided stationary blade portion **70**B. In a state where the abutting end FA**1** and the abutting end FB**2** are abutted with each other and the abutting end FA**2** and the abutting end FB**1** are abutted with each other, a gap S corresponding to the cutout K is formed between the one end **73***a***1** of the outer circumferential rim **73***a* of the divided stationary blade portion **70**A and the other end **73***b***2** of the outer circumferential rim **73***b* of the divided stationary blade portion **70**B. Similarly, a gap S corresponding to the cutout K is formed between the one end **73***b***1** of the outer circumferential rim **73***b* of the divided stationary blade portion **70**B and the other end **73***a***2** of the outer circumferential rim **73***a* of the divided stationary blade portion **70**A.

[0052] This gap S is determined based on maximum tolerance α of the circumferential length between both the abutting ends, maximum tolerance β between an outer circumferential surface of the stationary blade portion **70** assembled from the divided stationary blade portions and an inner circumferential surface of the spacer **8**, or the like.

(Detailed Description of Stator Blade **71**)

[0053] Although details will be described later, the stator blades **71** of this embodiment are manufactured by drawing. As shown in FIG. **4**, the stator blades **71** formed in the divided stationary blade portions **70**A, **70**B are extended in a radial manner with predetermined width in the circumferential direction between the outer circumferential rim **73***a* and the inner circumferential rim **72***a*, and inclined at a predetermined blade angle with respect to a stationary blade portion main body **70**H so as to form the plurality of exhaust openings **79**. That is, the stator blade **71** stands from and is connected to the stationary blade portion main body **70**H in a bent portion **70**R extended linearly in the radial direction on a plane of the stationary blade portion main body **70**H. The stator blade **71** is separated from the stationary blade portion main body **70**H on the side of a front end side portion **77** which is the opposite side of the stationary blade portion main body **70**H. A height of the front end side portion **77** of the stator blade **71** from the stationary blade portion main body **70**H, that is, a blade height is formed to be higher on the outer circumferential side than the inner circumferential side.

[0054] The stator blade **71** is formed into a rectangular shape elongated in the radial direction in a plan view. This rectangular shape is formed by the bent portion **70**R serving as a long side, the front end side portion **77** serving as a long side, an outer circumferential side end **71**So serving as a short side, and an inner circumferential side end **71**Si serving as a short side.

[0055] The divided stationary blade portions **70**A, **70**B respectively include inner circumferential side support portions **75** for connecting the inner circumferential side ends **71**Si of the stator blades **71** to the inner circumferential rim **72***a* or **72***b*, and outer circumferential side support portions **76**

for connecting the outer circumferential side ends **71**So of the stator blades **71** to the outer circumferential rim **73***a* or **73***b*.

[0056] The inner circumferential side support portion **75** is formed over the entire length of the inner circumferential side end **71**Si of the stator blade **71**. The outer circumferential side support portion **76** is formed in correspondence to a part of the outer circumferential side end **71**So of the stator blade **71**. That is, the outer circumferential side support portion **76** is provided from the bent portion **70**R where the stator blade **71** is bent from the stationary blade portion main body **70**H to an intermediate part of the front end side portion **77**, and an opening portion **78** is provided on the front end side. The opening portion **78** communicates with the exhaust opening **79** provided between the front end side portion **77** and the stationary blade portion main body **70**H.

[0057] As described above, since the stator blade **71** is supported by the outer circumferential side support portion **76** connected to the outer circumferential rim **73***a* and the inner circumferential side support portion **75** connected to the inner circumferential rim **72***a*, the stator blade has large rigidity. The blade height is greater on the outer circumferential side than the inner circumferential side. However, since the opening portion **78** is formed in the outer circumferential side end **71**So on the side of the front end side portion **77**, generation of cracking in the outer circumferential side support portion **76** can be suppressed at the time of the drawing.

(Manufacturing Method of Divided Stationary Blade Portion)

[0058] Next, referring to FIGS. **5** to **10**, a manufacturing method of the divided stationary blade portions **70**A, **70**B will be described.

[0059] The divided stationary blade portions **70**A and **70**B are manufactured by the same manufacturing method. A manufacturing method of the divided stationary blade portion **70**A as a representative will be described.

[0060] This manufacturing method includes a step of preparing a half-disc plate **70**P, a step of forming radial cut lines **81** in the half-disc plate **70**P and forming the cutout K in the one end **73***a***1** of the outer circumferential rim **73***a*, a step of forming openings **82** in the circumferential direction in outermost circumferential parts of the radial cut lines **81** of the half-disc plate **70**P, and a step of forming the stator blades **71** by the drawing.

[0061] Firstly, the half-disc plate **70**P serving as a metal half-disc member in which the half-disc opening **83** is provided on the inner circumferential side is prepared. An aluminum alloy, stainless steel, and the like can be used as a material of the half-disc plate **70**P.

[0062] As shown in FIG. **5**, the plurality of straight cut lines **81** is formed in a radial manner in the half-disc plate **70**P. The cutout K is formed in the one end **73***a***1** of the outer circumferential rim **73***a* at the same time or in a different step. A radial length of the cut lines **81** is a radial length of the stator blades **71**. The cut lines **81** and the cutout K can be formed by pressing or etching. Edges of the cut lines **81** serve as the front end side portions **77** after the drawing.

[0063] Next, as shown in FIG. **6**, the substantially rectangular openings **82** along an outer circumferential surface **84** of the half-disc plate **70**P are formed in outer circumferential ends of the cut lines **81**. Although the openings **82** are formed by the pressing for efficiency, the openings may be formed by the etching. The openings **82** serve as the opening portions **78** after the drawing. It should be noted that the cutout K may be not formed in the above step of forming the cut lines **81** but can be formed at the same time as formation of the openings **82** or after the formation.

[0064] By a die and a punch, the stator blades **71** are drawn from the half-disc plate **70**P. Hereinafter, referring to FIGS. **7** to **10**, the drawing will be described in detail.

[0065] FIG. **7** is an enlarged view of a region VII in FIG. **6**. In FIG. **7**, a region **76***a* shown by hatching is a region becoming the outer circumferential side support portion **76** for connecting the stationary blade portion main body **70**H and the outer circumferential rim **73***a* by the drawing. A length lo of the opening **82** is desirably less than a half of a length L of the entire outer circumferential side end **71**So of the stator blade **71**.

[0066] FIG. **8**A is a plan view of the punch, FIG. **8**B is a perspective view of the punch, FIG. **9**A is a plan view of the die, and FIG. **9**B is a perspective view of the die. FIGS. **10**A and **10**B are views for illustrating the method of forming the stator blade **71** by the drawing with using a punch PU and a die DI, FIG. **10**A is a sectional view taken along line Xa-Xa in FIG. **6** at the time of the drawing, and FIG. **10**B is a sectional view taken along line Xb-Xb in FIG. **6** at the time of the drawing.

[0067] As shown in FIGS. **8**A, **8**B, **10**A, and **10**B, the punch PU has an inclined portion PU**1** projecting toward the lower surface side of the stator blade **71** from the outer circumferential rim **73***a* for forming the outer circumferential side support portion **76** of the stator blade **71**. The punch also has an inclined portion PU**2** projecting toward the lower surface side of the stator blade **71** from the inner circumferential rim **72***a* for forming the inner circumferential side support portion **75** of the stator blade **71**. The punch PU includes a punch main body portion PU**3** having an inclined surface PU**3***a* projecting toward the front end side portion **77** from the bent portion **70**R of the stationary blade portion main body **70**H of the stator blade **71**, the inclined surface being formed to be upgrade toward the outer circumferential rim **73***a* from the inner circumferential rim **72***a*. An abutting end PU**3***b* substantially parallel to the axial direction of the rotor shaft **5** is formed at a position of the punch main body portion PU**3** corresponding to the front end side portion **77**. The abutting end PU**3***b* is to separate the front end side portion **77** of the stator blade **71** from the stationary blade portion main body **70**H.

[0068] As shown in FIGS. **9**A, **9**B, **10**A, and **10**B, the die DI has an inclined portion DI**1** recessed toward the upper surface side of the stator blade **71** from the side of the outer circumferential rim **73***a* for forming the outer circumferential side support portion **76** of the stator blade **71**. The die also has an inclined portion DI**2** recessed toward the upper surface side of the stator blade **71** from the side of the inner circumferential rim **72***a* for forming the inner circumferential side support portion **75** of the stator blade **71**. The die DI includes a die main body portion DI**3** having an inclined surface DI**3***a* recessed toward the front end side portion **77** from the bent portion **70**R of the stationary blade portion main body **70**H of the stator blade **71**, the inclined surface being formed to be downgrade toward the outer circumferential rim **73***a* from the inner circumferential rim **72***a*. An abutting end DI**3***b* substantially parallel to the axial direction of the rotor shaft **5** is formed at a position of the die main body portion DI**3** corresponding to the front end side portion **77**. The abutting end DI**3***b* is to separate the front end side portion **77** of the stator blade **71** from the stationary blade portion main body **70**H.

[0069] The half-disc plate **70**P is set on the die DI, the punch PU is pushed out in the arrow direction, and the drawing is performed to the half-disc plate **70**P, so that the stator blade **71** is manufactured. In this drawing, a three-dimensional plastic flow is generated in the region **76***a* of the diagonal lines of FIG. **7**, so that the outer circumferential side support portion **76** is formed. By the plastic deformation of the region **76***a,* the opening **82** is three-dimensionally deformed in the blade height direction from a flat shape, so that the opening portion **78** is formed. The stationary blade portion main body **70**H stands up from the bent portion **70**R (refer to FIG. **6**) into an inclined shape in such a manner that the cut line **81** formed in the half-disc plate **70**P becomes the front end side portion **77**, so that the stator blade **71** is formed. A space between the front end side portion **77** of the standing stator blade **71** and the stationary blade portion main body **70**H becomes the exhaust opening **79** (refer to FIG. **4**). The opening portion **78** formed in an outer circumferential side part of the stator blade **71** is formed so as to be connected continuously to the exhaust opening **79**.

[0070] According to the above embodiment described above, the following effects are obtained.

[0071] In the vacuum pump of the embodiment, the abutting ends FA**1** and FB**2** of the two divided stationary blade portions **70**A, **70**B are abutted with each other and the abutting ends FB**1** and the FA**2** are abutted with each other, so that the disc shape stationary blade portion **70** is formed. Each of the divided stationary blade portions **70**A, **70**B has the outer circumferential rim **73***a,* the inner circumferential rim **72***a* positioned in a front end on the inner circumferential side of the stationary blade portion **70**, and the exhaust openings **79** and the stator blades **71** provided between the outer circumferential rim **73***a* and the inner circumferential rim **72***a.* The stator blades **71** are extended in a radial manner with predetermined width in the circumferential direction between the outer circumferential rim **73***a* and the inner circumferential rim **72***a,* and inclined at a predetermined blade angle with respect to the stationary blade portion main body **70**H so as to form the plurality of exhaust openings **79**. In the abutting ends FA**1**, FB**2** (FB**1**, FA**2**) of the outer circumferential rims **73***a,* **73***b* where the plurality of divided stationary blade portions **70**A, **70**B is abutted with each other, in at least the one outer circumferential rim **73***a* (**73***b*), the cutout K forming a gap from the other facing outer circumferential rim **73***b* (**73***a*) is formed.

[0072] Therefore, even in a case where the circumferential length between the abutting ends FA**1** and FA**2** or FB**1** and FB**2** is formed to be longer than the designed size due to variation at the time of working, at the time of assembling the stationary blade portion **70**, the ends of the outer circumferential rims **73***a* of the divided stationary blade portions **70**A and **70**B can be suppressed from being overlapped with each other, or generation of warpage can be suppressed. In particular, the outer circumferential rims **73***a* are nipped by the spacers. Thus, when the ends of the outer circumferential rims **73***a* are overlapped with each other, positioning precision of the stationary blade portion **70** in the rotation shaft direction is deteriorated or the stationary blade portion **70** is not horizontally arranged but inclined. However, in the present embodiment, the ends of the outer circumferential rims **73***a* are not overlapped with each other. Thus, the positioning precision of the stationary blade portion **70** can be improved, so that the stationary blade portion **70** can be horizontally arranged. This effect is a unique and remarkable effect which cannot be obtained from Japanese Unexamined Patent Application Publication No. 2006-77713 described above.

[0073] Each of the divided stationary blade portions **70**A, **70**B is manufactured from a flat plate into the same shape. An abutting end surface of the inner circumferential rim **72***a* and an abutting end surface of the outer circumferential rim **73***a* are formed as a first abutting surface in the one abutting end FA**1** of the divided stationary blade portion **70**A. An abutting end surface of the inner circumferential rim **72***a,* an abutting end surface of the outer circumferential rim **73***a,* and an abutting end surface of the edge member **70**S forming the exhaust opening **79** are formed as a second abutting surface in the other abutting end FA**2**. The first abutting surface and the second abutting surface are abutted with each other so as to form the stationary blade portion **70**. Therefore, the stationary blade portion **70** can be formed by combining two divided stationary blade portions of one type, so that cost can be suppressed.

Embodiment 2

[0074] FIG. **11** is an enlarged perspective view of Embodiment 2 in major parts of the stationary blade portion of the present invention.

[0075] In Embodiment 2, different points from Embodiment 1 are as follows.

(1) In each of the divided stationary blade portions **70**A, **70**B, an outer circumferential side support portion **76**A for connecting the stator blade **71** and the outer circumferential rim **73***a* or **73***b* is formed over the entire length of the outer circumferential side end **71**So of the stator blade **71** as well as the inner circumferential side support portion **75**. That is, the opening portion **78** formed in Embodiment 1 for separating the front end side portion **77** from the outer circumferential side support portion **76** is not provided.

(2) Bending portions **72***a***3**, **72***b***3** bent at the substantially right angle from the abutting ends of the inner circumferential rims **72***a,* **72***b* are respectively provided in the inner circumferential rims **72***a,* **72***b* of the divided stationary blade portions **70**A, **70**B.

[0076] In a case where a blade height of the outer circumferential side support portion **76**A is not really high, without providing the opening portion **78** for separating the front end side portion **77** of the stator blade **71** from the outer circumferential side support portion **76**, no cracking is generated in the outer circumferential side support portion **76**A. Therefore, by providing the outer circumferential side support portion **76**A over the entire length of the outer circumferential side end **71**So of the stator blade **71**, rigidity can be further enhanced.

[0077] By respectively providing the bending portions **72***a***3**, **72***b***3** bent at the substantially right angle from the inner circumferential rims **72***a,* **72***b* in the inner circumferential rims **72***a,* **72***b* of the divided stationary blade portions **70**A, **70**B, a task of abutting the bending portions **72***a***3** and the **72***b***3** with each other is easily performed. Therefore, a task of assembling the stationary blade portion **70** can be efficiently performed.

[0078] In Embodiment 2, the same operations and effects as Embodiment 1 can be obtained.

[0079] Other elements are the same as Embodiment 1, corresponding configurations are given the same reference signs, and description thereof will be omitted.

[0080] It should be noted that although the bending portions **72***a***3**, **72***b***3** are respectively formed in the divided stationary blade portions **70**A, **70**B in the example, the bending portion **72***a***3** or **72***b***3** may be formed in only one of the divided stationary blade portions **70**A, **70**B.

[0081] In the structure of Embodiment 1, the bending portions **72***a***3**, **72***b***3** may be provided in both the members of or one of the divided stationary blade portions **70**A, **70**B.

Embodiment 3

[0082] FIG. **12** is an enlarged perspective view of Embodiment 3 in the major parts of the stationary blade portion of the present invention.

[0083] In Embodiment 3, different points from Embodiment 1 are as follows.

(1) The divided stationary blade portions **70**A, **70**B include no outer circumferential side support portion for connecting the outer circumferential side end **71**So of the stator blade **71** and the outer circumferential rim **73***a,* and no inner circumferential side support portion for connecting the inner circumferential side end **71**Si of the stator blade **71** and the inner circumferential rim **72***a.* That is, the inner and outer circumferential side ends **71**Si, **71**So of the stator blade **71** are respectively separated from the inner and outer circumferential rims **72***a,* **73***a* or **72***b,* **73***b* over the entire length.

(2) Only the one divided stationary blade portion **70**B among the divided stationary blade portions **70**A, **70**B includes the bending portion **72***b***3** bent at the substantially right angle from the inner circumferential rim **72***b* in the inner circumferential rim **72***b,* and the other divided stationary blade portion **70**A does not include a bending portion.

[0084] In a case where the blade height of the stator blade **71** from the stationary blade portion main body **70**H is not really high, there is no need for providing the inner and outer circumferential side support portions **75**, **76**.

[0085] Thereby, a die can be inexpensive and production efficiency can be enhanced.

[0086] Even when the bending portion **72***b***3** is provided in only one of the divided stationary blade portions **70**A, **70**B, in comparison to a structure where no bending portion is formed, the task of abutting the end **72***a***1** and the bending portions **72***b***3** with each other is easily performed, and the task of assembling the stationary blade portion **70** can be efficiently performed.

[0087] Also in Embodiment 3, the same operations and effects as Embodiment 1 can be obtained.

[0088] Other elements are the same as Embodiment 1, corresponding configurations are given the same reference signs, and description thereof will be omitted.

[0089] It should be noted that in Embodiment 3, the inner and outer circumferential side support portions **75**, **76** may be provided in one of inner and outer circumferential side parts of the divided stationary blade portions **70**A, **70**B, and no inner and outer circumferential side support portions **75**, **76** may be provided in the other.

[0090] As described above, the stationary blade portions **70** are arranged in multiple stages in parallel to the axial direction of the rotor **4**, and the blade height of the stator blade **71** is formed to be higher in the stationary blade portion **70** on the upper stage side than the stationary blade portion **70** on the lower stage side.

[0091] Therefore, the stationary blade portions **70** shown in Embodiments 1 to 3 may be differentiated in each stage. For example, the stationary blade portion **70** of Embodiment 1, the stationary blade portion **70** of Embodiment 2, and the stationary blade portion **70** of Embodiment 3 can be arranged in this order from the upper stage side toward the lower stage side. An uppermost stator blade **71***a* may be the stationary blade portion **70** manufactured by mechanical working.

[0092] The cutouts K provided in the outer circumferential rims **73***a,* **73***b* in the above configuration are not necessarily provided in all the stages of the stationary blade portions **70** but may be provided in only at least one stage of the stationary blade portion **70**.

[0093] In the example, the cutout K is provided in one side end of the outer circumferential rim **73***a* or **73***b* of each of the divided stationary blade portions **70**A, **70**B. However, the cutouts K may be provided in both side ends of the outer circumferential rim **73***a* and **73***b.*

[0094] The divided stationary blade portions **70**A, **70**B are not necessarily halved parts but may be not less than three divided parts.

[0095] In the example of the above embodiment, the compound type turbo-molecular pump including the blade exhaust portion and the threaded groove exhaust portion is shown as an example of a vacuum pump. However, the present invention can also be applied to a vacuum pump including only a blade exhaust portion.

[0096] In addition, the present invention can be applied with various modifications within a range of the gist of the invention. That is, as long as the present invention is a vacuum pump having an exhaust function portion in which stationary blade portions nipped by spacers are respectively arranged between rotating blade portions arranged in multiple stages, wherein in abutting ends of outer circumferential rims where a plurality of divided stationary blade portions is abutted with each other, in at least one of the outer circumferential rims, a cutout forming a gap from the other facing outer circumferential rim is formed, the invention is not limited to the embodiment and modified examples.

What is claimed is:

1. A vacuum pump having an exhaust function portion in which stationary blade portions nipped by spacers are respectively arranged between rotating blade portions arranged in multiple stages, wherein

each of the stationary blade portions is formed by two or more divided stationary blade portions,

each of the divided stationary blade portions has abutting ends in both circumferential ends, the stationary blade portion is formed by abutting the abutting ends of the divided stationary blade portions with each other,

each of the divided stationary blade portions has an outer circumferential rim nipped by the spacers, an inner circumferential rim positioned in a front end on the inner circumferential side of the stationary blade portion, and a plurality of stator blades formed between the outer circumferential rim and the inner circumferential rim, and

in abutting ends of the outer circumferential rims where the plurality of divided stationary blade portions is abutted with each other, at least one of the outer circumferential rims has a cutout forming a gap together with the other facing outer circumferential rim.

2. The vacuum pump according to claim **1**, wherein

each of the divided stationary blade portions is manufactured from a flat plate into the same shape,

an abutting end surface of the inner circumferential rim and an abutting end surface of the outer circumferential rim are formed as a first abutting surface in the one abutting end of the divided stationary blade portion, an end surface of the inner circumferential rim, an end surface of the outer circumferential rim, and an end surface of an edge member forming an opening portion are formed as a second abutting surface in the other abutting end, and

the first abutting surface and the second abutting surface are abutted with each other so as to form the stationary blade portion.

3. The vacuum pump according to claim **1**, wherein

the cutout is provided in the outer circumferential rim as a rectangular shape with a predetermined width in the circumferential direction and a predetermined length in a radial direction.

4. The vacuum pump according to claim **1**, wherein

a bending portion bent from the inner circumferential rim is provided in at least one of end surfaces of the inner circumferential rims where the plurality of divided stationary blade portions is abutted with each other.

5. The vacuum pump according to claim **1**, wherein

the gap is determined based on maximum tolerance α of circumferential length between both the abutting ends, and/or maximum tolerance β between an outer circumferential surface of the stationary blade portion assembled from the divided stationary blade portions and an inner circumferential surface of the spacer.

* * * * *