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(54) **VACUUM PUMP**

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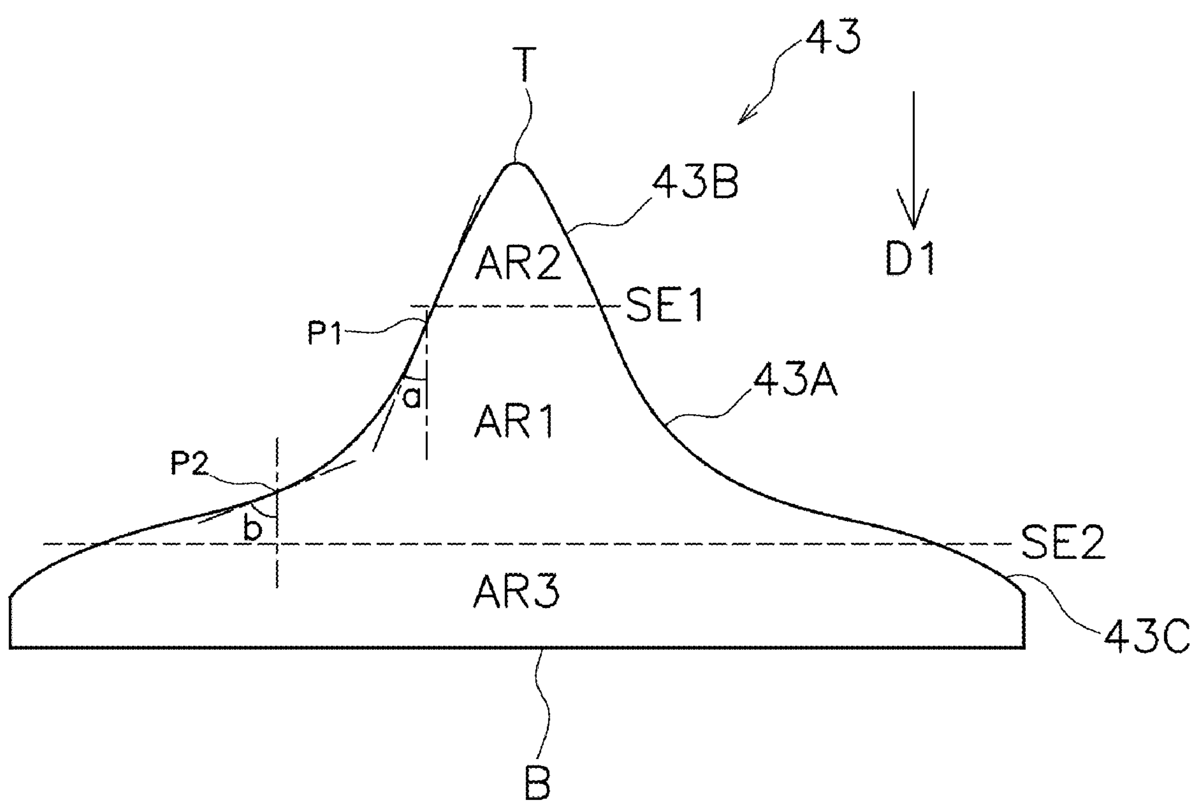
(57) **ABSTRACT**

A vacuum pump includes a housing having a suction port, a rotor housed in the housing and rotationally driven to suck gas through the suction port and pump the gas, and a lid member that covers a recess of the rotor. The lid member has a cone shape having a vertex on a side close to the suction port and having a bottom on a side close to the rotor. The generatrix of the cone shape includes a first curved portion having such a curve that an angle between a tangent to the generatrix and a gas flow direction increases from a vicinity of the vertex to a vicinity of the bottom.



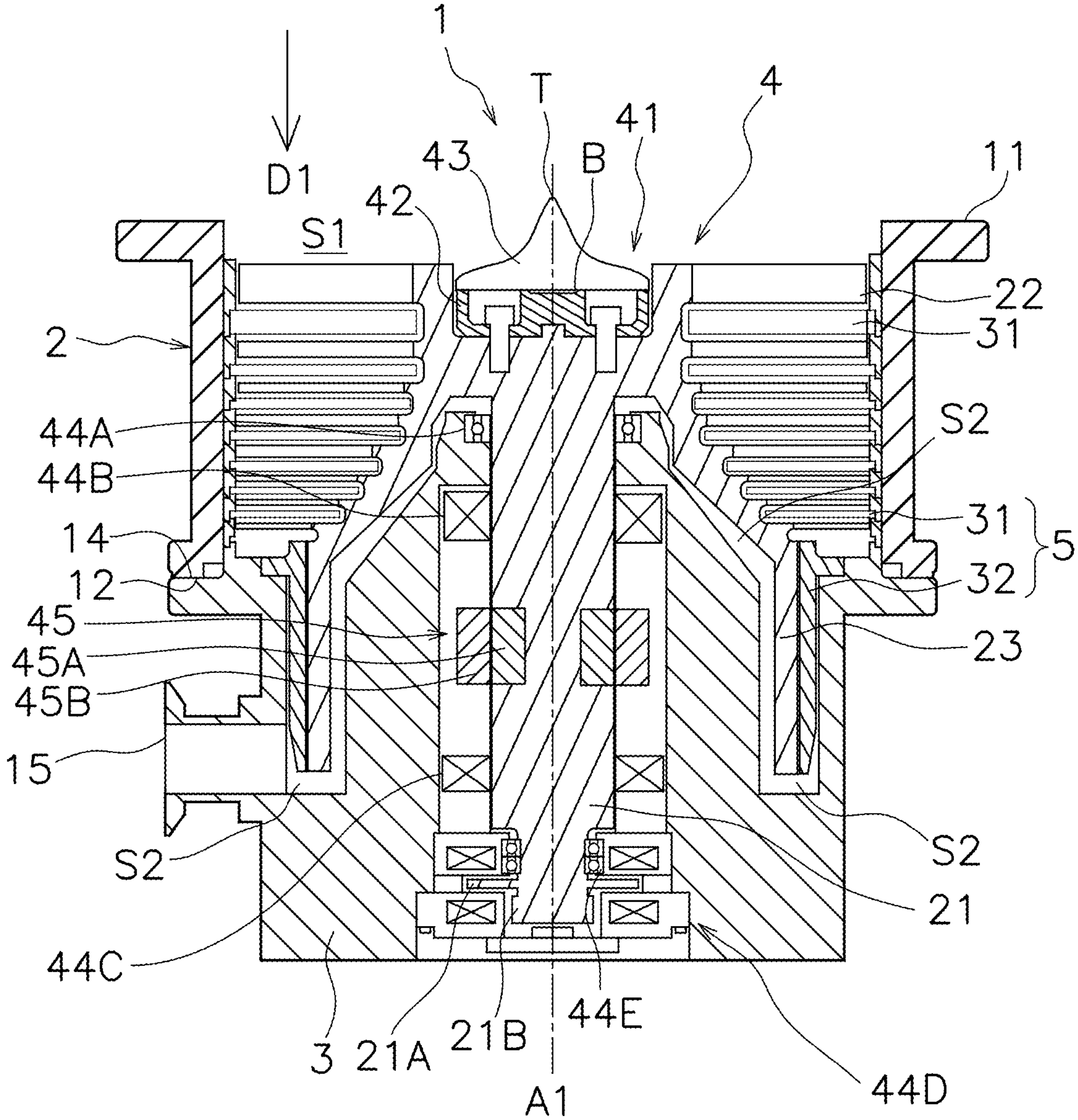

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FIG. 1

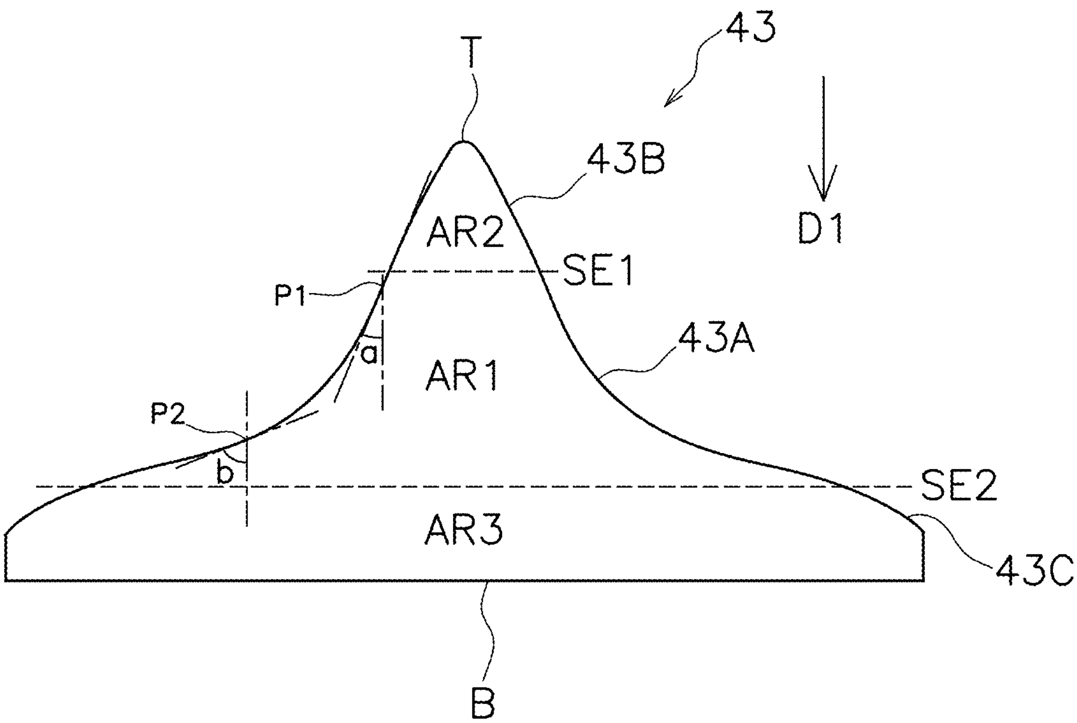

FIG. 2

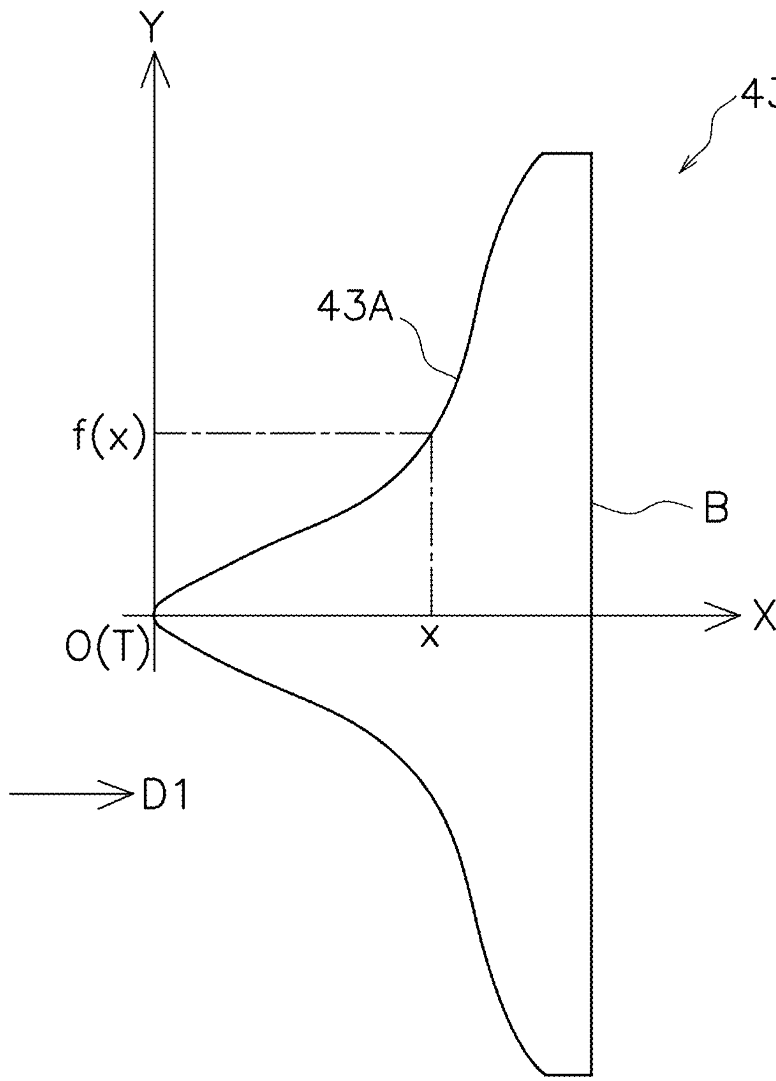

FIG. 3

VACUUM PUMP

[0001] This application claims priority under 35 U.S.C. § 119 to Japanese Patent Application No. 2024-19824 filed on Feb. 13, 2024. The entire disclosure of Japanese Patent Application No. 2024-19824 is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Technical Field

[0002] The present invention relates to a vacuum pump.

2. Background Art

[0003] There is a vacuum pump that sucks gas from an inside of a pumping target device and pumps the sucked gas to the outside by rotating a rotor having a rotor blade. The Rotor of the vacuum pump has a recess on a suction port side for sucking gas. There is a pumping target device described above that generates a predetermined solid (e.g., product generated in the pumping target device), and the solid may flow into the vacuum pump and accumulate in the recess of the rotor. In order to prevent the solid from accumulating in the recess of the rotor, a lid member that covers the recess is provided (see, e.g., U.S. Pat. No. 9,512,853, WO 2022/181464 A).

[0004] In some cases, a conventional lid member has a planar shape or a substantially hemispherical shape. The lid member having such a shape has a large surface perpendicular to a gas flow direction by the vacuum pump. The large surface perpendicular to the gas flow direction bounces back most of solids flown into the vacuum pump in a direction opposite to the gas flow direction. That is, the lid member having the planar shape or the substantially hemispherical shape bounces back the solids flown into the vacuum pump to, e.g., a pumping target device. In addition, in some cases, a conventional lid member has a linear inclined surface. However, since the inclined surface is not sufficiently inclined, such lid member also bounces back the solids flown into the vacuum pump to the pumping target device.

[0005] Thus, an object of the present invention is to prevent a solid from bouncing out of a vacuum pump while preventing the solid from accumulating in a recess of a rotor.

SUMMARY OF THE INVENTION

[0006] The vacuum pump according to one aspect of the present invention includes a housing, a rotor, and a lid member. The housing has a suction port. The rotor is housed in the housing, and is rotationally driven to suck gas through the suction port and pump the gas. The rotor has a recess in a portion facing the suction port. The lid member covers the recess of the rotor. In the above-described vacuum pump, the lid member has a cone shape having a vertex on a side close to the suction port and having a bottom on a side close to the rotor. The generatrix of the cone shape includes a first curved portion having such a curve that an angle between a tangent to the generatrix and a gas flow direction increases from the vicinity of the vertex to the vicinity of the bottom.

[0007] The lid member of the vacuum pump according to one aspect of the present invention has the cone shape having the vertex on the side close to the suction port and having the bottom on the side close to the rotor. The generatrix of the cone shape includes the first curved portion having such a curve that the angle between the tangent to the generatrix and the gas flow direction increases from the vicinity of the vertex to the vicinity of the bottom. The lid member in such a shape has a surface at an angle close to the gas flow direction on the side close to the suction port. Thus, on the surface of the lid member on the side close to the suction port, a solid is not bounced toward the suction port, and does not come out of the vacuum pump. On the other hand, the surface of the lid member on the side close to the bottom is placed at a position close to an angle perpendicular to the gas flow direction but away from the center of the lid member. Thus, on the side close to the bottom, great centrifugal force acts on the surface of the lid member due to rotation of the rotor. With this centrifugal force, the solid existing on the side close to the bottom of the lid member is blown in a direction close to a direction perpendicular to the gas flow direction. Thus, even on the surface of the lid member on the side close to the bottom, the solid is not bounced toward the suction port, and does not come out of the vacuum pump.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a sectional view of a vacuum pump;

[0009] FIG. **2** is a view showing a detailed configuration of a lid member; and

[0010] FIG. **3** is a view schematically showing that a first curved portion is expressed by a monotonically increasing function for a distance from a vertex.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0011] Hereinafter, a vacuum pump will be described with reference to FIG. **1**. FIG. **1** is a sectional view of a vacuum pump **1**. The vacuum pump **1** includes a housing **2**, a base **3**, a rotor **4**, and a stator **5**.

[0012] The housing **2** includes a first end portion **11**, a second end portion **12**, and a first internal space S**1**. The first end portion **11** is provided with a suction port **13**. The suction port **13** is connected to the inside of a pumping target device such that gas is flowable therebetween. The first internal space S**1** communicates with the suction port **13**. The second end portion **12** is located opposite to the first end portion **11** in the axial direction of the rotor **4** (hereinafter, simply referred to as an "axial direction A**1**"). The second end portion **12** is connected to the base **3**. The base **3** includes a base end portion **14**. The base end portion **14** is connected to the second end portion **12** of the housing **2**. The base **3** is, for example, a member made of aluminum.

[0013] The rotor **4** is housed in the internal space of the housing **2**. The rotor **4** includes a shaft **21**. The shaft **21** extends in the axial direction A**1**. The shaft **21** is rotatably housed in the base **3**. A lower portion of the shaft **21** is provided with a thrust disc **21**A. A target **21**B is screwed to the lower end of the shaft **21**.

[0014] A recess **41** is provided on the side of the rotor **4** facing the suction port **13** (i.e., the upper end surface of the rotor **4**). A balance disc **42** is attached to the bottom surface of the recess **41**. The balance disc **42** is a member for balancing the rotor **4**. A lid member **43** is attached to an upper end portion of the balance disc **42**. The lid member **43** is disposed such that the center axis of the lid member **43**

coincides with or is close to the rotation axis of the rotor **4**. The lid member **43** is fixed onto the balance disc **42** with, e.g., a screw.

[0015] The lid member **43** is a member that covers the recess **41** of the rotor **4**. The lid member **43** prevents a solid having passed through the suction port **13** from the pumping target device and having flowed into the housing **2** from entering the recess **41**. By providing the lid member **43**, it is possible to prevent accumulation of the solid in the recess **41** of the rotor **4**.

[0016] The rotor **4** includes plural stages of rotor blades **22** and a rotor cylindrical portion **23**. Each of the plural stages of rotor blades **22** is connected to the shaft **21** with inclined with respect to the axial direction A**1**. The plural stages of rotor blades **22** are spaced apart from each other in the axial direction A**1**. The plural stages of rotor blades **22** extend radially about the shaft **21**. Note that in the drawings, only one of the plural stages of rotor blades **22** is denoted by a reference sign, and the reference signs of the other rotor blades **22** are omitted. The rotor cylindrical portion **23** is placed below the plural stages of rotor blades **22**. The rotor cylindrical portion **23** extends in the axial direction A**1**.

[0017] The stator **5** is disposed on the outer peripheral side of the rotor **4**. The stator **5** includes plural stages of stator blades **31** and a stator cylindrical portion **32**. Each of the plural stages of stator blades **31** is connected to the inner surface of the housing **2** with inclined in a direction opposite to the inclination of the rotor blade **22**. For example, when the rotor blade **22** is inclined from a suction side to an exhaust side, the stator blade **31** is inclined from the exhaust side to the suction side. On the other hand, when the rotor blade **22** is inclined from the exhaust side to the suction side, the stator blade **31** is inclined from the suction side to the exhaust side. The inclination directions of the rotor blade **22** and the stator blade **31** can be appropriately determined according to, e.g., the rotation direction of the rotor **4**.

[0018] The plural stages of stator blades **31** are spaced apart from each other in the axial direction A**1**. Each of the plural stages of stator blades **31** is disposed between adjacent ones of the plural stages of rotor blades **22**. The plural stages of stator blades **31** extend radially about the shaft **21**. Note that in the drawings, only two of the plural stages of stator blades **31** are denoted by reference signs, and the reference signs of the other stator blades **31** are omitted. The stator cylindrical portion **32** is fixed in contact with the base **3**. The stator cylindrical portion **32** is placed so as to face the outer peripheral surface of the rotor cylindrical portion **23** with a slight gap in the radial direction of the rotor cylindrical portion **23**. A spiral groove is provided in the inner peripheral surface of the stator cylindrical portion **32** facing the rotor cylindrical portion **23**.

[0019] As shown in FIG. **1**, an exhaust space S**2** is formed further downstream of pumping downstream end portions of the rotor cylindrical portion **23** and the stator cylindrical portion **32**. Pumping target gas pumped from the pumping target device is guided to the exhaust space S**2**. The exhaust space S**2** communicates with an exhaust port **15**. The exhaust port **15** is provided in the base **3**. Another vacuum pump is connected to the exhaust port **15**. Note that the pumping downstream side represents a side closer to the exhaust space S**2** in the axial direction A**1**. A pumping downstream direction represents a direction toward the exhaust space S**2**. The pumping downstream direction is referred to as a flow direction D**1** of the pumping target gas.

[0020] The vacuum pump **1** includes bearings **44**A, **44**E, magnetic bearings **44**B to **44**D, and a motor **45**. The bearings **44**A, **44**E are attached to the base **3** at positions at which the shaft **21** is housed. The bearings **44**A, **44**E rotatably support the shaft **21**. The bearings **44**A, **44**E are ball bearings. The magnetic bearings **44**B to **44**D are bearings that support the shaft **21** by magnetic force. Of these magnetic bearings, the magnetic bearings **44**B, **44**C are radial magnetic bearings that support the shaft **21** in the radial direction. The magnetic bearing **44**D is a thrust magnetic bearing that supports the shaft **21** in the axial direction.

[0021] The motor **45** rotationally drives the rotor **4**. The motor **45** includes a motor rotor **45**A and a motor stator **45**B. The motor rotor **45**A is attached to the shaft **21**. The motor stator **45**B is attached to the base **3**. The motor stator **45**B is disposed so as to face the motor rotor **45**A.

[0022] In the vacuum pump **1**, the plural stages of rotor blades **22** and the plural stages of stator blades **31** form a turbo-molecular pump portion. The rotor cylindrical portion **23** and the stator cylindrical portion **32** form a screw groove pump portion. In the vacuum pump **1**, when the rotor **4** is rotated by the motor **45**, the pumping target gas flows into the first internal space S**1** from the inside of the pumping target device through the suction port **13**. The pumping target gas in the first internal space S**1** passes through the turbo-molecular pump portion and the screw groove pump portion, and is guided to the exhaust space S**2**. The pumping target gas in the exhaust space S**2** is pumped through the exhaust port **15**. As a result, the inside of the pumping target device attached to the suction port **13** is brought into a high vacuum state.

[0023] As described above, the vacuum pump **1** is provided with the lid member **43** that covers the recess **41** of the rotor **4**. By providing the lid member **43**, it is possible to prevent the solid having flowed in from the pumping target device through the suction port **13** from accumulating in the recess **41**. In the present embodiment, further, the surface shape of the lid member **43** is determined such that the solid bounced on the surface of the lid member **43** is not bounced in a direction opposite to the flow direction D**1** of the pumping target gas and come out of the vacuum pump **1** through the suction port **13**.

[0024] Hereinafter, the lid member **43** will be described in detail with reference to FIGS. **1** and **2**. FIG. **2** is a view showing a detailed configuration of the lid member **43**. As shown in FIG. **1**, the lid member **43** has a cone shape having a vertex T on a side close to the suction port **13** and having a bottom B on a side close to the rotor **4**. Specifically, the lid member **43** has a protruding conical shape with a vertex T side portion smaller.

[0025] More specifically, the lid member **43** has a conical shape expanding from the side close to the vertex T toward the side close to the bottom B. In other words, the generatrix of the lid member **43** is defined by such a curve that an angle between a tangent to the generatrix and the flow direction D**1** of the pumping target gas increases from the vicinity of the vertex T to the vicinity of the bottom B. For example, as shown in FIG. **2**, an angle a between a tangent P**1** to a point on the generatrix of the lid member **43** on the side close to the vertex T and the flow direction D**1** of the pumping target gas is smaller than an angle b between a tangent P**2** to a point on the generatrix of the lid member **43** on the side close to the bottom B and the flow direction D**1** of the pumping target gas. Here, the "generatrix of the lid member **43**" means a line forming the side surface of the lid member **43**, and corresponds to a side portion when the lid member **43** is cut along the flow direction D**1**.

[0026] As shown in FIGS. **1** and **2**, the generatrix of the lid member **43** has two points (referred to as inflection points) at which the curvature of the curve changes. The generatrix of the lid member **43** can be divided into three regions at these two inflection points, and has different curves for each region. Specifically, as shown in FIG. **2**, the generatrix of the lid member **43** can be divided into three regions by a first separatrix SE**1** corresponding to the inflection point on the side close to the vertex T and a second separatrix SE**2** corresponding to the inflection point on the side close to the bottom B. The intermediate region is referred to as a first region AR**1**, the region on the vertex T side is referred to as a second region AR**2**, and the region on the bottom B side is referred to as a third region AR**3**. Further, the generatrix of the first region AR**1** is referred to as a first curved portion **43**A, the generatrix of the second region AR**2** is referred to as a second curved portion **43**B, and the generatrix of the third region AR**3** is referred to as a third curved portion **43**C. That is, the generatrix of the lid member **43** includes three different curves of the first curved portion **43**A, the second curved portion **43**B, and the third curved portion **43**C.

[0027] Of these curved portions, the first curved portion **43**A has such a curve that the angle between the tangent to the generatrix and the flow direction D**1** of the pumping target gas increases from the vicinity of the vertex T to the vicinity of the bottom B. As shown in FIG. **3**, on an X-Y coordinate system in which the vertex T is an origin O, an axis parallel to the flow direction D**1** is an X-axis, and an axis perpendicular to the flow direction D**1** is a Y-axis, the first curved portion **43**A can be expressed as a monotonically increasing function of the value of the X-axis. Specifically, for an arbitrary value x of the X-axis, the shape of the first curved portion **43**A can be expressed as a monotonically increasing function f(x). The monotonically increasing function f(x) can be, for example, a monotonically increasing polynomial (e.g., $a_1x^2+a_2x^3+ \ldots +a_nx^n$ ($a_1, a_2, \ldots, a_n$: constant)) or an exponential function (e.g., M^{Nx} (M, N: number greater than 1)) of a second or higher order for x. FIG. **3** is a view schematically showing that the first curved portion **43**A is expressed by the monotonically increasing function for a distance from the vertex T.

[0028] In the above-described X-Y coordinate system, the value (x) of the X-axis corresponds to the distance from the vertex T in the flow direction D**1**. Since the first curved portion **43**A is expressed by the monotonically increasing function f(x) for x, it can be paraphrased that the first curved portion **43**A is expressed by the monotonically increasing function for the distance from the vertex T. The value (f(x)) of the Y-axis corresponds to a distance between the first curved portion **43**A and the center axis (i.e., X-axis) of the lid member **43**. Since the first curved portion **43**A is expressed by the monotonically increasing function f(x) for the distance from the vertex T, the first curved portion **43**A is placed at a position away from the center axis of the lid member **43** as approaching the bottom B (as the x value increases).

[0029] By expressing the first curved portion **43**A by the monotonically increasing function for the distance x from the vertex T, the first curved portion **43**A can be easily designed and manufactured. Note that the second curved portion **43**B and the third curved portion **43**C may also have shapes expressed as the function for the distance x from the vertex T.

[0030] The above-described first curved portion **43**A has a surface at an angle close to the flow direction D**1** on the side close to the suction port **13**. Thus, on the surface of the first curved portion **43**A on the side close to the suction port **13**, the solid is not bounced toward the suction port **13**, and does not come out of the vacuum pump **1**.

[0031] On the other hand, the surface of the first curved portion **43**A on the side close to the bottom B approaches a right angle to the flow direction D**1**, but is placed at a position away from the center axis of the lid member **43**. Thus, great centrifugal force acts on the surface of the first curved portion **43**A on the side close to the bottom B due to rotation of the rotor **4**. With this centrifugal force, the solid having reached the side of the first curved portion **43**A close to the bottom B is blown in a direction close to a direction perpendicular to the flow direction D**1**. Thus, on the surface of the first curved portion **43**A on the side close to the bottom B, the solid is not bounced toward the suction port **13**, and does not come out of the vacuum pump **1**.

[0032] The second curved portion **43**B is a curve connecting the vertex T of the lid member **43** and an upper end portion of the first curved portion **43**A. Of the second curved portion **43**B, a portion corresponding to the vertex T has a small hemispherical shape. Since the portion corresponding to the vertex T is formed in the hemispherical shape, it is possible to suppress the solid having flowed in through the suction port **13** from bouncing toward the suction port **13** as compared with a case where the vertex T is pointed. In a portion of the second curved portion **43**B other than the vertex T, an angle between a tangent to such a portion and the flow direction D**1** is small. Specifically, the angle between the tangent to the portion of the second curved portion **43**B other than the vertex T and the flow direction D**1** is smaller than the angle between the tangent to the first curved portion **43**A and the flow direction D**1**. Thus, the solid is not bounced on such a portion of the second curved portion **43**B toward the suction port **13**, and does not come out of the vacuum pump **1**.

[0033] As shown in FIG. **1**, the portion of the second curved portion **43**B corresponding to the vertex T protrudes from the upper end surface of the rotor **4** facing the suction port **13**. With this configuration, it is possible to suppress turbulence of the flow of the pumping target gas at the vertex T of the lid member **43**. That is, a flow along the curved side surface of the lid member **43** is easily generated, and the solid can be moved along this flow. As a result, it is possible to suppress the solid from bouncing toward the suction port **13** and coming out of the vacuum pump **1**.

[0034] The third curved portion **43**C is a curve connecting a lower end portion of the first curved portion **43**A and the bottom B of the lid member **43**. The tangent to the third curved portion **43**C has an angle close to a right angle to the flow direction D**1**, but the third curved portion **43**C is placed at a position away from the center axis of the lid member **43**. Thus, great centrifugal force acts on the third curved portion **43**C due to rotation of the rotor **4**. With this centrifugal force, the solid having reached the third curved portion **43**C is blown in a direction close to a direction perpendicular to the flow direction D**1**. Thus, even on the third curved portion **43**C, the solid is not bounced toward the suction port **13**, and does not come out of the vacuum pump **1**.

[0035] As shown in FIGS. **1** and **2**, the bottom B of the lid member **43** has a side parallel to the flow direction D**1**. Specifically, an angle between a tangent to a portion of the third curved portion **43**C on the side close to the bottom B and the flow direction D**1** is smaller than an angle between a tangent to a portion of the third curved portion **43**C close to the first curved portion **43**A and the flow direction D**1**.

[0036] One embodiment of the present invention has been described above, but the present invention is not limited to the above-described embodiment and various changes can be made without departing from the gist of the invention.

[0037] The vacuum pump **1** according to the above-described embodiment is a pump configured such that the turbo-molecular pump formed by the plural stages of rotor blades **22** and the plural stages of stator blades **31** and the screw groove pump formed by the rotor cylindrical portion **23** and the stator cylindrical portion **32** are integrated. However, the screw groove pump may be omitted. Alternatively, the rotor blades **22** and the stator blades **31** may be omitted, and the vacuum pump **1** may include only the screw groove pump. That is, the above-described lid member **43** can also be applied to a vacuum pump including only a turbo-molecular pump or a vacuum pump including only a screw groove pump.

[0038] In the above-described embodiment, the lid member **43** is attached onto the balance disc **42**. The present invention is not limited thereto, and the lid member **43** may be directly fixed to the recess **41** of the rotor **4** with, e.g., a screw.

[0039] It is understood by those skilled in the art that the plurality of exemplary embodiments described above is specific examples of the following aspects.

[0040] (First Aspect) A vacuum pump (e.g., vacuum pump **1**) according to a first aspect includes a housing (e.g., housing **2**), a rotor (e.g., rotor **4**), and a lid member (e.g., lid member **43**). The housing has a suction port (e.g., suction port **13**). The rotor is housed in the housing, and is rotationally driven to suck gas through the suction port and pump the gas. The rotor has a recess (e.g., recess **41**) in a portion facing the suction port. The lid member covers the recess of the rotor. In the above-described vacuum pump, the lid member has a cone shape having a vertex (e.g., vertex T) on a side close to the suction port and having a bottom (e.g., bottom B) on a side close to the rotor. The generatrix of the cone shape includes a first curved portion (e.g., first curved portion **43**A) having such a curve that an angle between a tangent to the generatrix and a gas flow direction increases from the vicinity of the vertex to the vicinity of the bottom.

[0041] The lid member of the vacuum pump according to the first aspect has the cone shape having the vertex on the side close to the suction port and having the bottom on the side close to the rotor. The generatrix of the cone shape includes the first curved portion having such a curve that the angle between the tangent to the generatrix and the gas flow direction increases from the vicinity of the vertex to the vicinity of the bottom. The lid member in such a shape has a surface at an angle close to the gas flow direction on the side close to the suction port. Thus, on the surface of the lid member on the side close to the suction port, a solid is not bounced toward the suction port, and does not come out of the vacuum pump. On the other hand, the surface of the lid member on the side close to the bottom is placed at a position close to an angle perpendicular to the gas flow direction but away from the center of the lid member. Thus, great centrifugal force acts on the surface of the lid member on the side close to the bottom due to rotation of the rotor. With this centrifugal force, the solid existing on the side close to the bottom of the lid member is blown in a direction close to a direction perpendicular to the gas flow direction. Thus, even on the surface of the lid member on the side close to the bottom, the solid is not bounced toward the suction port, and does not come out of the vacuum pump.

[0042] (Second Aspect) In the vacuum pump according to the first aspect, the generatrix of the cone shape of the lid member may include the first curved portion and a second curved portion (e.g., second curved portion **43**B) closer to the vertex than the first curved portion. In the vacuum pump according to the second aspect, the vertex of the lid member and the first curved portion can be continuously and smoothly connected.

[0043] (Third Aspect) In the vacuum pump according to the second aspect, a portion of the second curved portion corresponding to the vertex of the lid member may have a hemispherical shape. In the vacuum pump according to the third aspect, it is possible to suppress the solid having flowed in through the suction port from bouncing toward the suction port as compared with a case where the vertex of the lid member is pointed.

[0044] (Fourth Aspect) In the vacuum pump according to any one of the first to third aspects, the first curved portion may be expressed by a monotonically increasing polynomial or an exponential function of a second or higher order for a distance from the vertex of the lid member. In the vacuum pump according to the fourth aspect, the first curved portion can be expressed by a mathematical formula, and therefore, the lid member can be easily designed and manufactured.

[0045] (Fifth Aspect) In the vacuum pump according to any one of the first to fourth aspects, the vertex of the lid member may protrude from the surface of the rotor facing the suction port. In the vacuum pump according to the fifth aspect, it is possible to suppress turbulence of the flow of the gas at the vertex of the lid member. That is, a flow along the curved side surface of the lid member is easily generated, and the solid can be moved along this flow. As a result, it is possible to suppress the solid from bouncing toward the suction port and coming out of the vacuum pump.

[0046] (Sixth Aspect) In the vacuum pump according to the second aspect, the generatrix of the cone shape may further include a third curved portion (e.g., third curved portion **43**C) closer to the bottom than the first curved portion. In the vacuum pump according to the sixth aspect, the lid member can have a more optimal shape in which the solid is not bounced toward the suction port.

[0047] (Seventh Aspect) In the vacuum pump according to the sixth aspect, an angle between a tangent to a portion of the third curved portion on a side close to the bottom and the gas flow direction may be smaller than an angle between a tangent to a portion of the third curved portion on a side close to the first curved portion and the gas flow direction. In the vacuum pump according to the seventh aspect, the bottom of the lid member and the side surface other than the bottom can be smoothly connected.

[0048] (Eighth Aspect) In the vacuum pump according to the second aspect, a portion of the second curved portion other than the vertex may be formed such that an angle between a tangent to the portion and the gas flow direction is smaller than an angle between a tangent to the first curved portion and the gas flow direction. In the vacuum pump according to the eighth aspect, it is possible to suppress the solid from bouncing toward the suction port on the portion of the second curved portion other than the vertex.

[0049] (Ninth Aspect) In the vacuum pump according to any one of the first to eighth aspects, the lid member may have a conical shape expanding from the side close to the vertex toward the side close to the bottom. In the vacuum pump according to the ninth aspect, on the surface on the side close to the suction port, the solid is not bounced toward the suction port and does not come out of the vacuum pump. Great centrifugal force acts on the surface on the side close to the bottom of the lid member due to rotation of the rotor, and therefore, the solid is not bounced toward the suction port and does not come out of the vacuum pump.

[0050] (Tenth Aspect) In the vacuum pump according to any one of the first to ninth aspects, the first curved portion may have a surface at an angle close to the gas flow direction on the side close to the suction port such that the solid is not bounced toward the suction port. Further, on the side close to the bottom of the lid member, the first curved portion may be placed at a position close to an angle perpendicular to the gas flow direction but away from the center of the lid member such that the solid is blown by centrifugal force in a direction close to a direction perpendicular to the gas flow direction and is not bounced toward the suction port. In the vacuum pump according to the tenth aspect, the solid is not bounced toward the suction port, and does not come out of the vacuum pump.

What is claimed is:

1. A vacuum pump comprising:

a housing having a suction port;

a rotor housed in the housing, rotationally driven to suck gas through the suction port and pump the gas, and having a recess in a portion facing the suction port; and

a lid member that covers the recess of the rotor,

wherein the lid member has a cone shape having a vertex on a side close to the suction port and having a bottom on a side close to the rotor, and

a generatrix of the cone shape includes a first curved portion having such a curve that an angle between a tangent to the generatrix and a gas flow direction increases from a vicinity of the vertex to a vicinity of the bottom.

2. The vacuum pump according to claim **1**, wherein the generatrix of the cone shape includes the first curved portion and a second curved portion closer to the vertex than the first curved portion.

3. The vacuum pump according to claim **2**, wherein a portion of the second curved portion corresponding to the vertex has a hemispherical shape.

4. The vacuum pump according to claim **1**, wherein the first curved portion is expressed by a monotonically increasing polynomial or an exponential function of a second or higher order for a distance from the vertex.

5. The vacuum pump according to claim **1**, wherein the vertex protrudes from a surface of the rotor facing the suction port.

6. The vacuum pump according to claim **2**, wherein the generatrix of the cone shape further includes a third curved portion closer to the bottom than the first curved portion.

7. The vacuum pump according to claim **6**, wherein an angle between a tangent to a portion of the third curved portion on a side close to the bottom and the gas flow direction is smaller than an angle between a tangent to a portion of the third curved portion on a side close to the first curved portion and the gas flow direction.

8. The vacuum pump according to claim **2**, wherein a portion of the second curved portion other than the vertex is formed such that an angle between a tangent to the portion and the gas flow direction is smaller than an angle between a tangent to the first curved portion and the gas flow direction.

9. The vacuum pump according to claim **1**, wherein the lid member has a conical shape expanding from a side close to the vertex toward a side close to the bottom.

10. The vacuum pump according to claim **1**, wherein the first curved portion has a surface at an angle close to the gas flow direction on the side close to the suction port such that a solid is not bounced toward the suction port, and on a side close to the bottom of the lid member, is placed at a position close to an angle perpendicular to the gas flow direction but away from a center of the lid member such that the solid is blown by centrifugal force in a direction close to a direction perpendicular to the gas flow direction and is not bounced toward the suction port.

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