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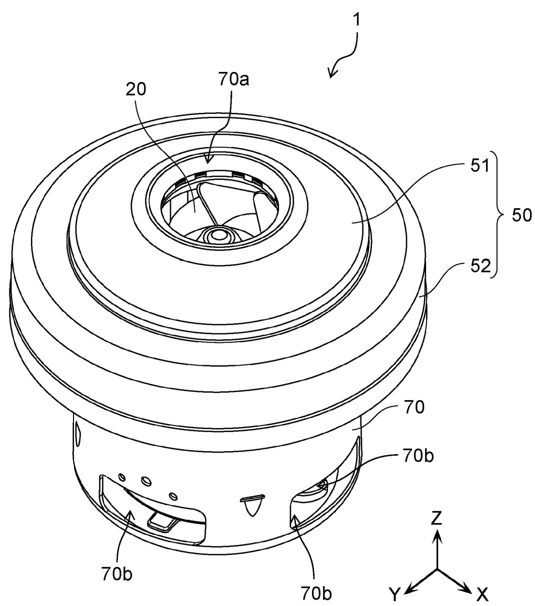
(54) **ELECTRIC BLOWER**

(57) A centrifugal fan included in an electric blower has: a shroud having an air suction port; a hub facing the shroud; and a plurality of blades each disposed between the shroud and the hub. In each of the plurality of blades, an inner periphery-side end portion is located inside the air suction port, and is inclined to locate a shroud-side portion of the inner periphery-side end portion on a positive side of a rotation direction of the centrifugal fan with respect to a hub-side portion. A radius of curvature in an in-plane direction of a main surface of the hub in an end surface on a hub side is larger in an outer periphery-side end portion than in the inner periphery-side end portion, an angle formed by a side surface of the hub-side portion and the main surface of the hub is larger in the outer periphery-side end portion than in the inner periphery-side end portion, and an inlet angle in an inner periphery-side portion is equal to or more than 40 degrees.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an electric blower. The present disclosure particularly relates to an electric blower that blows air by rotating a centrifugal fan by power of an electric motor.

BACKGROUND ART

[0002] Electric blowers are used in various electric apparatuses such as vacuum cleaners. In an electric blower mounted on a vacuum cleaner, a centrifugal fan for obtaining a high suction pressure is used. The centrifugal fan is attached to a rotary shaft of an electric motor of the electric blower and rotates at high speed to generate a desired air pressure.

[0003] For example, centrifugal fan 20X having a configuration shown in Figs. 11A and 11B is used as the electric blower. Fig. 11A is a top view of conventional centrifugal fan 20X. Fig. 11B is a cross-sectional view of conventional centrifugal fan 20X taken along line XIb-XIb in Fig. 11A.

[0004] As shown in Figs. 11A and 11B, conventional centrifugal fan 20X includes shroud 21X having air suction port 20a, hub 22X facing shroud 21X, and a plurality of blades 23X sandwiched between shroud 21X and hub 22X.

[0005] In centrifugal fan 20X shown in Figs. 11A and 11B, backward blades each extending in a direction opposite to a rotation direction from inner periphery-side end portion 23b toward outer periphery-side end portion 23c is used as blade 23X. In centrifugal fan 20X shown in Figs. 11A and 11B, in order to improve efficiency, inner periphery-side end portion 23b of each of blades 23X slightly protrudes to a central side from an opening end edge of air suction port 20a. That is, when air suction port 20a is viewed from above, tips of inner periphery-side end portions 23b of blades 23X are located inside an opening of air suction port 20a. In centrifugal fan 20X configured as described above, air sucked from air suction port 20a is compressed to a high pressure by rotation of centrifugal fan 20X and discharged from exhaust ports 20b.

[0006] Conventionally, this type of centrifugal fan has been disclosed in PTL 1. In a centrifugal fan disclosed in PTL 1, in order to obtain a high suction pressure, backward blades are used as blades, and an outlet angle on an outer peripheral side of each of the blades is set to be substantially less than or equal to 40 degrees. Furthermore, in the centrifugal fan disclosed in PTL 1, in order to improve efficiency, an inner periphery-side end portion of each of the blades protrudes to a central side from an opening end edge of an air suction port. At this time, if the inner periphery-side end portion of the blade is configured to be substantially perpendicular to a hub as shown in Figs. 11A and 11B, collision loss caused when the air sucked from the air suction port collides with the inner periphery-side end portion of the blade increases, and the suction pressure decreases.

[0007] Therefore, in the centrifugal fan disclosed in PTL 1, the inner periphery-side end portion of the blade is inclined. In this case, taking centrifugal fan 20X shown in Figs. 11A and 11B as an example, inner periphery-side end portion 23b of blade 23X is inclined with respect to a main surface of hub 22X so that shroud-side portion 23b 1 is located on a positive side in the rotation direction of centrifugal fan 20X with respect to hub-side portion 23b2.

[0008] On the other hand, there is also known a technique for obtaining a high suction pressure by providing an electric blower with a separate component instead of devising a structure of the centrifugal fan itself. For example, PTL 2 discloses an electric blower capable of bringing about a high suction pressure by providing an inducer on an air suction port side of a centrifugal fan, the inducer being made of resin and rectifying air sucked into the centrifugal fan.

[0009] In recent years, as the electric blower, it is desired to obtain a higher suction pressure. In this case, in the centrifugal fan disclosed in PTL 1, it is conceivable to further extend the inner periphery-side end portion of the blade toward the central side of the air suction port. However, when the inner periphery-side end portion of the blade is extended toward the central side, there is a risk that the inner periphery-side end portion of the blade is plastically deformed by centrifugal force when the centrifugal fan rotates.

[0010] At this time, by inclining the inner periphery-side end portion of the blade, not only the collision loss caused by the air sucked from the air suction port colliding with the inner periphery-side end portion of the blade can be suppressed, but also a length of the portion protruding from the air suction port in the inner periphery-side end portion of the blade is shorter in the shroud-side portion than in the hub-side portion, so that the deformation of the inner periphery-side end portion of the blade due to the centrifugal force is less likely to occur.

[0011] However, in the structure of the centrifugal fan disclosed in PTL 1, there is a limit to the extension length when the inner periphery-side end portion of the blade is extended toward the central side of the air suction port. That is, even if the inner periphery-side end portion of the blade is extended toward the central side of the air suction port in order to obtain a high suction pressure, the inner periphery-side end portion of the blade is plastically deformed by the centrifugal force.

[0012] In the electric blower using the centrifugal fan disclosed in PTL 2, a high suction pressure can be obtained. However, since the inducer is separately provided, a material cost and a manufacturing cost increase. When the inducer is provided, a weight of the centrifugal fan increases and vibration of the electric blower increases.

Citation List

Patent Literatures

[0013]

PTL 1: Japanese Patent No. 2757501
PTL 2: Japanese Patent No. 3796974

SUMMARY OF THE INVENTION

[0014] The present disclosure has been made to solve the above problems. An object of the present disclosure is to provide an electric blower capable of suppressing deformation of a blade due to a centrifugal force and bringing about a high suction pressure without providing an inducer.

[0015] In order to achieve the above object, one aspect of an electric blower according to the present disclosure includes: a rotor having a rotary shaft; and a centrifugal fan attached to the rotary shaft, the centrifugal fan including: a shroud having an air suction port; a hub facing the shroud; and a plurality of blades each having a shape extending in a direction opposite to a rotation direction of the centrifugal fan from an inner periphery-side end portion to an outer periphery-side end portion, the plurality of blades being disposed between the shroud and the hub, wherein in each of the plurality of blades, the inner periphery-side end portion is located inside the air suction port when viewed from a stacking direction of the shroud and the hub, and is inclined to locate a shroud-side portion of the inner periphery-side end portion on a positive side of the rotation direction with respect to a hub-side portion, a radius of curvature in an in-plane direction of a main surface of the hub in an end surface on a hub side is larger in the outer periphery-side end portion than in the inner periphery-side end portion, an angle formed by a side surface of the hub-side portion and the main surface of the hub is larger in the outer periphery-side end portion than in the inner periphery-side end portion, and an inlet angle in an inner periphery-side portion is equal to or more than 40 degrees.

[0016] Moreover, it is preferable that the air suction port is circular when the centrifugal fan is viewed from above, and a diameter of a virtual circle formed by connecting tips of the inner periphery-side end portions of the plurality of blades is less than or equal to 87% of a diameter of the air suction port.

[0017] Moreover, it is preferable that the air suction port is circular when the centrifugal fan is viewed from above, and in each of the plurality of blades, an angle formed by a circle concentric with the air suction port and having a diameter smaller than the diameter of the air suction port, and the end surface of the blade on the hub side is larger than the inlet angle.

[0018] Moreover, it is preferable that in each of the plurality of blades, the angle formed by the side surface of the hub-side portion in the inner periphery-side end portion and the main surface of the hub is less than or equal to 75 degrees, and the side surface of the hub-side portion in the outer periphery-side end portion is perpendicular to the main surface of the hub.

[0019] Moreover, it is preferable that in each of the plurality of blades, an outlet angle of the outer periphery-side portion is less than or equal to 40 degrees.

[0020] Moreover, it is preferable that the air suction port is circular when the centrifugal fan is viewed from above, and a diameter of a virtual circle formed by connecting tips on the hub side of the inner periphery-side end portions of the plurality of blades is smaller than a diameter of a virtual circle formed by connecting tips on the shroud side of the inner periphery-side end portions of the plurality of blades.

[0021] As described above, even if an inducer is not provided, deformation of the blade due to a centrifugal force can be suppressed, and a high suction pressure can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

Fig. 1 is an external perspective view of an electric blower according to an exemplary embodiment.
Fig. 2 is a cross-sectional view of the electric blower according to the exemplary embodiment.
Fig. 3 is an exploded perspective view of the electric blower according to the exemplary embodiment with a fan case and a centrifugal fan removed.
Fig. 4 is an exploded perspective view of the centrifugal fan according to the exemplary embodiment.
Fig. 5 is a top view of the centrifugal fan according to the exemplary embodiment.
Fig. 6 is a top view of the centrifugal fan with a shroud removed.
Fig. 7A is a top view of the centrifugal fan according to the exemplary embodiment.
Fig. 7B is a cross-sectional view of the same centrifugal fan taken along line VIIb-VIIb in Fig. 7A.
Fig. 8 is a view showing a relationship between a hub and a blade in the centrifugal fan according to the exemplary embodiment.
Fig. 9 is an enlarged cross-sectional view of the centrifugal fan according to the exemplary embodiment.
Fig. 10 is a diagram showing a relationship between a stress of the blade in the centrifugal fan according to the exemplary embodiment, and a length of a portion protruding from an opening end edge of an air suction port toward a central side in an inner periphery-side end portion of the blade.
Fig. 11A is a top view of a conventional centrifugal fan.
Fig. 11B is a cross-sectional view of the conventional centrifugal fan taken along line XIb-XIb in Fig. 11A.

DESCRIPTION OF EMBODIMENTS

[0023] Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the drawings. Note that each of the exemplary embodiments described below illustrates one specific example of the present disclosure. Therefore, numerical values, shapes, materials, components, disposition positions and connection modes of the components, and the like described in the following exemplary embodiments are merely examples, and are not intended to limit the present disclosure. Thus, of the components in each of the following exemplary embodiments, components that are not recited in the independent claim will be described herein as optional components.

[0024] Moreover, in the present description and the drawings, an X axis, a Y axis, and a Z axis indicate three axes of a three-dimensional orthogonal coordinate system. The X axis and the Y axis are axes orthogonal to each other and orthogonal to the Z axis. In the present exemplary embodiment, a Z-axis direction is a direction of shaft center C of rotary shaft 11a.

[0025] Note that each of the drawings is a schematic view, and is not necessarily strictly shown. In each of the drawings, substantially the same components are denoted by the same reference marks, and redundant description will be omitted or simplified.

(Exemplary embodiment)

[0026] First, the following describes an overall configuration of electric blower 1 according to an exemplary embodiment with reference to Figs. 1 to 3. Fig. 1 is an external perspective view of electric blower 1 according to the exemplary embodiment. Fig. 2 is a cross-sectional view of electric blower 1. Fig. 2 shows a cross section (XZ cross section) taken along a plane passing through shaft center C of rotary shaft 11a. Fig. 3 is an exploded perspective view of electric blower 1 with fan case 50 and centrifugal fan 20 removed. Note that Fig. 2 only shows a line drawing appearing on the cross section. Bold arrows shown in Fig. 2 each indicate a flow of air sucked into electric blower 1.

[0027] As shown in Figs. 1 to 3, electric blower 1 includes electric motor 10, centrifugal fan 20 attached to rotary shaft 11a that electric motor 10 has, fixing member 30 for fixing centrifugal fan 20 to rotary shaft 11a, air guide 40 into which air discharged from centrifugal fan 20 flows, fan case 50 that covers centrifugal fan 20, fan case spacer 60 attached to fan case 50, motor case 70 that accommodates electric motor 10, and bracket 80. Electric blower 1 can be used, for example, in an electric cleaner.

[0028] Electric motor 10 is a fan motor that rotates centrifugal fan 20. As one example, electric motor 10 is a DC electric motor to which a DC power supply is input. In the present exemplary embodiment, electric motor 10 is a commutator motor with brushes.

[0029] Specifically, electric motor 10 includes rotor 11, stator 12, first bearing 13, and second bearing 14, commutator 15, and brushes 16.

[0030] Rotor 11 has rotary shaft 11a. Rotor 11 rotates around shaft center C of rotary shaft 11a as a rotation center. Rotor 11 rotates at high speed of, for example, 50,000 revolutions per minute (rpm). In the present exemplary embodiment, rotor 11 is an inner rotor, and is disposed inside stator 12 as shown in Fig. 2.

[0031] Rotary shaft 11a is an elongated shaft that is to be a center when rotor 11 rotates. Rotary shaft 11a is, for example, a metal rod. Rotary shaft 11a is fixed to a center of rotor 11. Specifically, rotary shaft 11a is fixed to rotor core 11b in a state passing through a center of rotor core 11b of rotor 11 so as to extend on both sides of rotor 11. Rotary shaft 11a is fixed to rotor core 11b by, for example, press-fitting or shrink-fitting into a center hole of rotor core 11b.

[0032] As one example, rotor 11 is an armature and has rotor core 11b, and winding coil 11c (rotor coil) wound around rotor core 11b via an insulator. Fig. 2 schematically shows winding coil 11c.

[0033] Rotor core 11b is an armature core around which winding coil 11c is wound. Rotor core 11b is a magnetic body made of a magnetic material. As one example, rotor core 11b is a stacked body in which a plurality of electromagnetic steel plates are stacked in a direction of shaft center C of rotary shaft 11a (shaft center direction). Note that rotor core 11b is not limited to the stacked body of electromagnetic steel plates, but may be a bulk body made of a magnetic material. To rotor core 11b is fixed rotary shaft 11a. Rotary shaft 1 1a is fixed to rotor core 1 1b in the state passing through the center of rotor core 1 1b. Rotor core 11b has a plurality of teeth protruding in a radial direction that is a direction orthogonal to shaft center C of rotary shaft 11a.

[0034] Winding coil 11c has a coil wound around each of a plurality of teeth of rotor core 11b. This coil is wound onto each of the teeth a plurality of times. Specifically, the coil is a distributed winding coil that is wound around the teeth with distributed winding via the insulator.

[0035] Winding coil 11c is electrically connected to commutator 15. Specifically, winding coil 11c is electrically connected to commutator pieces of commutator 15. The teeth of rotor core 11b are disposed with a minute air gap between the teeth and stator 12. By a current flowing through winding coil 11c via commutator 15, rotor 11 generates a magnetic force that acts on stator 12.

[0036] Stator 12 is located to face rotor 11, and generates the magnetic force that acts on rotor 11. Specifically, stator 12 is disposed so as to surround rotor core 1 1b of rotor 11. Stator 12 configures a magnetic circuit together with rotor 11 that is an armature.

[0037] Stator 12 is configured such that N poles and S poles alternately appear in a circumferential direction on an air gap surface. In this case, stator 12 may be configured such that a plurality of permanent magnets are disposed in the circumferential direction, or may include a stator core having a plurality of teeth portions that generate a main magnetic flux, and a winding coil wound around the stator core. Stator 12 is a magnetic field assembly obtained by winding a winding coil around a stator core with a plurality of electromagnetic steel sheets stacked. Stator 12 is fixed to, for example, motor case 70.

[0038] First bearing 13 and second bearing 14 support rotary shaft 11a. First bearing 13 supports one end portion of rotary shaft 11a (end portion on a centrifugal fan 20 side). Second bearing 14 supports another end portion of rotary shaft 11a (end portion on an opposite side of centrifugal fan 20 side). First bearing 13 and second bearing 14 are bearings that support rotary shaft 11a. As one example, first bearing 13 and second bearing 14 are ball bearings. However, the present invention is not limited thereto, and another bearing such as a sliding bearing may be used. In this way, rotary shaft 11a are rotatably held by first bearing 13 and second bearing 14. Note that first bearing 13 is fixed to bracket 80, and second bearing 14 is fixed to a bottom portion of motor case 70.

[0039] The one end portion of rotary shaft 11a protrudes from first bearing 13. Centrifugal fan 20 is attached to a tip portion of rotary shaft 11a protruding from first bearing 13. In rotary shaft 11a, a portion where centrifugal fan 20 is attached (portion on the first bearing 13 side) is referred to as an output shaft, and a portion on the opposite side of centrifugal fan 20 side (portion on the second bearing 14 side) is referred to as a counter output shaft.

[0040] Commutator 15 is attached to rotary shaft 11a. Therefore, commutator 15 rotates together with rotary shaft 11a. In the present exemplary embodiment, commutator 15 is located on first bearing 13 side of rotor core 11b. Specifically, commutator 15 is attached to a portion between rotor core 11b and first bearing 13 in rotary shaft 11a.

[0041] Commutator 15 has the plurality of commutator pieces arranged in an annular shape so as to surround rotary shaft 11a. The plurality of commutator pieces are insulated and separated from each other in a rotation direction of rotary shaft 11a. Each of the plurality of commutator pieces is electrically connected to winding coil 11c of rotor 11.

[0042] Each of brushes 16 is in contact with commutator 15. Brush 16 is a power supply brush for supplying electric power to winding coil 11c of rotor 11. When brush 16 comes into contact with commutator 15, an armature current supplied to brush 16 flows to winding coil 11c via commutator 15. Brush 16 is made of a conductive material. As one example, brush 16 is a conductive carbon brush made of carbon, and is an elongated substantially rectangular parallelepiped.

[0043] Brush 16 is disposed so as to be in sliding contact with commutator 15. In the present exemplary embodiment, a pair of the brushes 16 is provided. The pair of brushes 16 is disposed to face each other with commutator 15 sandwiched. Each of brushes 16 is in sliding contact with commutator 15 by receiving a pressing force from a brush spring such as a torsion spring, and is disposed to be movable in the radial direction from an outer periphery of rotary shaft 11a toward shaft center C. Brushes 16 are accommodated in, for example, a brush holder.

[0044] Centrifugal fan 20 is one example of a rotary fan, and sucks air by rotating. Specifically, centrifugal fan 20 sucks air into an outer casing (housing) configured of fan case 50 and motor case 70. By using centrifugal fan 20 as a rotary fan, a high suction pressure can be obtained. In general, while there is a sirocco centrifugal fan of a high air volume and high pressure type as the centrifugal fan, a turbo centrifugal fan of a low air volume and high pressure type is used in the present exemplary embodiment.

[0045] Centrifugal fan 20 is attached to a predetermined portion of rotary shaft 11a that electric motor 10 has, is rotated by rotation of rotary shaft 11a. Centrifugal fan 20 is attached to the tip portion on one side of rotary shaft 11a. Centrifugal fan 20 can be fixed to rotary shaft 11a by, for example, press-fitting rotary shaft 11a into a through hole provided in centrifugal fan 20. When centrifugal fan 20 is rotated by driving of electric motor 10, an air pressure is generated, and air is sucked from air suction port 50a of fan case 50, passes through an inside of centrifugal fan 20, and then is discharged from centrifugal fan 20. The air discharged from centrifugal fan 20 flows into air guide 40.

[0046] Centrifugal fan 20 has air suction port 20a (intake port) for sucking air and exhaust ports 20b (blowout ports) for discharging the air sucked from air suction port 20a. Centrifugal fan 20 has shroud 21 having air suction port 20a, hub 22 facing shroud 21, and a plurality of blades 23 disposed between shroud 21 and hub 22. A detailed configuration of centrifugal fan 20 will be described later.

[0047] Centrifugal fan 20 is fixed to rotary shaft 11a by fixing member 30. Fixing member 30 has fan boss 31, first abutting plate 32, second abutting plate 33, and fan stopper 34. Fan boss 31 and fan stopper 34 function as fastening nuts and each have a screw hole screwed with rotary shaft 11a. Fan boss 31, first abutting plate 32, second abutting plate 33, and fan stopper 34 are made of a metal material.

[0048] When centrifugal fan 20 is attached to rotary shaft 11a, hub 22 of centrifugal fan 20 is sandwiched between first abutting plate 32 and second abutting plate 33, and first abutment plate 32 and second abutment plate 33 sandwiching hub 22 are further sandwiched and pressurized by fan boss 31 screwed to rotary shaft 11a, and fan stopper 34. This allows fixing member 30 to pressurize and hold centrifugal fan 20 with respect to rotary shaft 11a.

[0049] The air discharged from centrifugal fan 20 flows into air guide 40. Air guide 40 has a function of forming a flow path of an air flow. For example, air guide 40 has a function of rectifying flows of the air discharged from centrifugal fan 20 and smoothly flowing the rectified air into motor case 70. Specifically, air guide 40 guides the air compressed by centrifugal fan 20 to an inside of motor case 70 while gradually returning the air to an atmospheric pressure.

[0050] Air guide 40 has a plurality of diffuser blades 41. Each of the plurality of diffuser blades 41 is plate-shaped, curved in an arc, and disposed radially. Specifically, the plurality of diffuser blades 41 are placed in a vortex shape. While air guide 40 is made of, for example, a resin material, this is not restrictive, and air guide 40 may be made of a metal material.

[0051] Air guide 40 is disposed with a gap from side wall portion 52 of fan case 50. The air that has flowed into air guide 40 passes through a ventilation passage configured of the plurality of diffuser blades 41, passes through the gap between air guide 40 and side wall portion 52 of fan case 50, and flows into motor case 70.

[0052] Fan case 50 is a casing that accommodates centrifugal fan 20. Fan case 50 is a cover that covers centrifugal fan 20 and air guide 40. As one example, fan case 50 is a metal cover made of a metal material. However, fan case 50 may be a resin cover made of a resin material.

[0053] Fan case 50 has lid portion 51 that covers upper portions of centrifugal fan 20 and air guide 40, and side wall portion 52 that covers side portions of centrifugal fan 20 and air guide 40. Fan case 50 has air suction port 50a (intake port) for sucking outside air. Air suction port 50a is a circular through hole provided in a central portion of lid portion 51. Air suction port 50a of fan case 50 faces air suction port 20a of centrifugal fan 20.

[0054] Fan case 50 is fixed to motor case 70. Specifically, side wall portion 52 of fan case 50 is connected to an opening end of opening portion 70a of motor case 70, which allows fan case 50 and motor case 70 to be fixed to each other.

[0055] Fan case spacer 60 is attached to fan case 50. Fan case spacer 60 is a thin ringshaped tubular body having an opening corresponding to air suction port 50a of fan case 50. Specifically, fan case spacer 60 is attached to lid portion 51 of fan case 50 so as to surround air suction port 50a of fan case 50. Fan case spacer 60 closes off an annular gap formed between air suction port 20a of centrifugal fan 20 and air suction port 50a of fan case 50. An opening of fan case spacer 60 communicates with air suction port 20a of centrifugal fan 20. An opening diameter of fan case spacer 60 is approximately equal to an opening diameter of air suction port 20a of centrifugal fan 20.

[0056] When centrifugal fan 20 rotates, a pressure near each of exhaust ports 20b of centrifugal fan 20 becomes high. Therefore, an air pressure difference is generated in a space path between shroud 21 of centrifugal fan 20 and lid portion 51 of fan case 50, and a circulating flow from exhaust port 20b of centrifugal fan 20 toward air suction port 50a of fan case 50 is about to be generated. However, providing fan case spacer 60 can reduce the above-described circulating flow. That is, by providing fan case spacer 60, the pressure can be prevented from escaping, and air blowing efficiency of electric blower 1 can be improved as compared with a case where fan case spacer 60 is not provided.

[0057] Motor case 70 is a casing that accommodates electric motor 10. Specifically, motor case 70 accommodates parts configuring electric motor 10, such as rotor 11 and stator 12. Motor case 70 is an outer member (outer shell) of electric blower 1 and electric motor 10. Motor case 70 is, for example, a metal case made of a metal material.

[0058] Motor case 70 is a casing (frame) having a bottomed cylindrical shape with opening portion 70a. Motor case 70 has the bottom portion and a cylindrical side wall portion. Opening portion 70a of motor case 70 is covered with fan case 50.

[0059] Moreover, in the bottom portion and the side wall portion of motor case 70, a plurality of exhaust ports 70b for discharging the air sucked by the rotation of centrifugal fan 20 are provided. That is, exhaust ports 70b are blow-out ports for blowing out the air sucked into motor case 70 by centrifugal fan 20. Motor case 70 also functions as a bracket (first bracket), and second bearing 14 is fixed to the bottom portion of motor case 70.

[0060] Furthermore, bracket 80 (second bracket) is disposed so as to partially cover opening portion 70a of motor case 70. For example, bracket 80 is disposed so as to extend across opening portion 70a of motor case 70. Bracket 80 is provided with a plurality of openings. The air rectified by air guide 40 passes through the openings of bracket 80 and a portion not covered with bracket 80 of motor case 70,and flows into motor case 70. Bracket 80 is made of, for example, a resin material. However, the material is not limited thereto, and bracket 80 may be made of a metal material. Note that first bearing 13 is fixed to bracket 80.

[0061] In electric blower 1 configured as described above, when rotor 11 of electric motor 10 rotates, centrifugal fan 20 attached to rotary shaft 1 1a of rotor 11 rotates, and the air is sucked into fan case 50 from air suction port 50a of fan case 50. The air sucked from air suction port 50a of fan case 50 flows into centrifugal fan 20 from air suction port 20a of centrifugal fan 20, is centrifugally blown toward a radial outside of centrifugal fan 20, and is discharged from exhaust ports 20b. At this time, the air sucked into centrifugal fan 20 is compressed to a high pressure by centrifugal fan 20. The air discharged from centrifugal fan 20 flows into air guide 40 surrounding centrifugal fan 20, is guided to side wall portion 52 of fan case 50 by diffuser blades 41 that air guide 40 has, becomes a swirling flow, and flows into motor case 70. The swirling flow flowing into motor case 70 is then discharged to an outside of electric blower 1 from exhaust ports 70b of motor case 70 while cooling rotor 11 and stator 12 of electric motor 10.

[0062] Next, a detailed configuration of centrifugal fan 20 used in electric blower 1 according to the present exemplary embodiment will be described in detail with reference to Figs. 4 to 9 while referring to Figs. 2 and 3. Fig. 4 is an exploded perspective view of centrifugal fan 20 according to the exemplary embodiment. Fig. 5 is a top view of same centrifugal fan 20. Fig. 6 is a top view of centrifugal fan 20 with shroud 21 removed. Fig. 7A is a top view of the centrifugal fan according to the exemplary embodiment. Fig. 7A is a top view of centrifugal fan 20 according to the exemplary embodiment. Fig. 7B is a cross-sectional view of the same centrifugal fan taken along line VIIb-VIIb in Fig. 7A. Fig. 8 is a view showing a relationship between hub 22 and blade 23 in same centrifugal fan 20. Fig. 9 is enlarged cross-sectional view of the same centrifugal fan.

[0063] Note that while Fig. 8 is a cross-sectional view taken along line VIII-VIII in Fig. 6, only blade 23A of six blades 23 is shown.

[0064] As shown in Figs. 4 to 9, centrifugal fan 20 is a fan assembly configured of shroud 21, hub 22, and the plurality of blades 23.

[0065] Shroud 21 and hub 22 are a pair of fan plates stacked with a gap therebetween. Of shroud 21 and hub 22, shroud 21 is an upper plate located on an upstream side (fan case 50 side), and hub 22 is a lower plate located on a downstream side (motor case 70 side). When centrifugal fan 20 is viewed from above, an outer shape of shroud 21 and an outer shape of hub 22 are the same. The outer shapes of shroud 21 and hub 22 in top view are circular.

[0066] The plurality of blades 23 are fan blades disposed between shroud 21 and hub 22. The plurality of blades 23 are disposed so as to erect with respect to shroud 21 and hub 22. The plurality of blades 23 are sandwiched between shroud 21 and hub 22. While in the present exemplary embodiment, six blades 23 are used, a number of blades 23 is not limited to six. For example, the number of blades 23 may be nine, eleven, or the like.

[0067] Each of shroud 21, hub 22, and blades 23 is made of a sheet metal and is configured of a metal plate having a constant thickness. In the present embodiment, each of shroud 21, hub 22, and blades 23 is configured of an aluminum plate. Shroud 21, hub 22, and the plurality of blades 23 are fixed by caulking.

[0068] As described above, centrifugal fan 20 has air suction port 20a for sucking air. Air suction port 20a is provided in shroud 21. Air suction port 20a provided in shroud 21 is a through hole and faces air suction port 50a of fan case 50 as shown in Fig. 2. When centrifugal fan 20 is viewed from above, air suction port 20a is circular.

[0069] Shroud 21 is a flat, substantially frustoconical tubular body. Air suction port 20a is provided in a top portion of shroud 21. Shroud 21 having such a shape can be formed by drawing a circular flat plate having a through hole corresponding to air suction port 20a into a flat substantially truncated cone shape.

[0070] As shown in Figs. 4 and 7A, shroud 21 has a plurality of through holes 21a. The plurality of through holes 21a are each formed in a slit shape so as to extend along an extending direction of each of blades 23. As one example, each of the plurality of through holes 21a is an elongated square hole. The plurality of through holes 21a are formed in one-to-one correspondence with a plurality of first protruded portions 23a1 of each of blades 23. Each of first protruded portions 23a1 of blade 23 is inserted into each of through holes 21a.

[0071] Hub 22 is disposed facing shroud 21 with a predetermined gap therebetween. Hub 22 is a flat circular plate.

[0072] As shown in Fig. 4, hub 22 has a plurality of through holes 22a. The plurality of through holes 22a are each formed in a slit shape so as to extend along the extending direction of each of blades 23. As one example, each of the plurality of through holes 22a is an elongated square hole. The plurality of through holes 22a are formed in one-to-one correspondence with a plurality of second protruded portions 23a2 of each of blades 23. Each of second protruded portions 23a2 of blade 23 is inserted into each of through holes 22a. Note that the shape and the size of each of through hole 22a of hub 22 are the same as the shape and the size of each of through holes 21a of shroud 21, but are not limited thereto.

[0073] Additionally, circular through hole 22b is provided in a central portion of hub 22. Rotary shaft 11a of rotor 11 is inserted into through hole 22b. By inserting rotary shaft 11a into the through hole 22b and fixing hub 22 to rotary shaft 11a with fixing member 30, centrifugal fan 20 can be fixed to rotary shaft 11a.

[0074] As shown in Figs. 4 and 7A, each of blades 23 has the plurality of first protruded portions 23a1 provided on an end surface on a shroud 21 side and the plurality of second protruded portions 23a2 provided on an end surface on a hub 22 side. First protruded portions 23a1 are protrusions provided so as to protrude toward the shroud 21 side. Second protruded portions 23a2 are protrusions provided so as to protrude toward the hub 22 side.

[0075] The first protruded portions 23a1 are provided at positions corresponding to through holes 21a of shroud 21, and are inserted into through holes 21a. A length (protrusion amount) of each of first protruded portions 23a1 is set to be longer than a plate thickness of shroud 21. As a result, when first protruded portions 23a1 are inserted into through holes 21a of shroud 21, tip portions of first protruded portions 23a1 protrude from through holes 21a.

[0076] Second protruded portions 23a2 are provided at positions corresponding to through holes 22a of hub 22, and are inserted into through holes 22a. A length (protrusion amount) of each of second protruded portions 23a2 is set to be longer than the plate thickness of hub 22. As a result, when second protruded portions 23a2 are inserted into through holes 22a of hub 22, tip portions of second protruded portions 23a2 protrude from through holes 22a.

[0077] Blades 23 can be fixed to shroud 21 and hub

22 by crushing and caulking the tip portions of first protruded portions 23a1 protruding from through holes 21a of shroud 21, and crushing and caulking the tip portions of second protruded portions 23a2 protruding from through holes 22a of hub 22. That is, first protruded portions 23a1 and second protruded portions 23a2 are protrusions for caulking and fixing. Note that each of blades 23 having the first protruded portions 23a1 and second protruded portions 23a2 can be formed, for example, by punching a metal plate configuring blade 23.

[0078] As shown in Fig. 6, each of the plurality of blades 23 is curved when centrifugal fan 20 is viewed from above. The plurality of blades 23 are disposed at equal intervals in a circumferential direction, and are arranged radially in a vortex manner.

[0079] Each of the plurality of blades 23 is a backward blade, and has a shape extending in a direction opposite to the rotation direction of centrifugal fan 20 from inner periphery-side end portion 23b to outer periphery-side end portion 23c. In other words, each of blades 23 is curved so as to extend in the rotation direction of centrifugal fan 20 from outer periphery-side end portion 23c to inner periphery-side end portion 23b.

[0080] As shown in Figs. 7A and 7B, a space surrounded by two adjacent blades 23, shroud 21, and hub 22 is a ventilation passage through which the air flowing into centrifugal fan 20 from air suction port 20a passes. An opening radially outside the ventilation passage is exhaust port 20b. A plurality of the ventilation passages are formed in a vortex manner along a plane normal to shaft center C of rotary shaft 11a. That is, exhaust ports 20b open in a direction orthogonal to shaft center C of rotary shaft 11a (radial direction), and the plurality of exhaust ports 20b are formed along a circumferential direction of centrifugal fan 20. Since blade 23 is a backward blade, the ventilation passage between two adjacent blades 23 is curved so as to extend in the direction opposite to the rotation direction of centrifugal fan 20 from inner periphery-side end portion 23b to outer periphery-side end portion 23c of blade 23.

[0081] As shown in Figs. 4 and 7A to 9, in each of blades 23 formed so as to be curved, a radius of curvature in an in-plane direction of a main surface (hub surface) of hub 22 in hub-side end surface 23d, which is an end surface on the hub 22 side, is larger in outer periphery-side end portion 23c than in inner periphery-side end portion 23b. That is, when centrifugal fan 20 is viewed from above, in each of blades 23, the radius of curvature of hub-side end surface 23d in outer periphery-side end portion 23c is larger than the radius of curvature of hub-side end surface 23d in inner periphery-side end portion 23b. In other words, in each of blades 23, the radius of curvature of hub-side end surface 23d in inner periphery-side end portion 23b is smaller than the radius of curvature of hub-side end surface 23d in outer periphery-side end portion 23c.

[0082] In the present exemplary embodiment, a curve (line indicated by a thick line in Fig. 9) forming hub-side end surface 23d in each of blades 23 is configured by combination of a plurality of arcs having different radii of curvature. Specifically, the curve forming hub-side end surface 23d in each of blades 23 is configured of combination of four arcs having different radii of curvature. These four radii of curvature decrease in order from outer periphery-side end portion 23c to inner periphery-side end portion 23b. Note that the curve forming hub-side end surface 23d of each of blades 23 may be an involute curve. The curve forming the shroud-side end surface in each of blades 23 is the same as the curve forming the hub-side end surface 23d.

[0083] As shown in Figs. 5 and 7A, in each of the plurality of blades 23, inner periphery-side end portion 23b protrudes toward a central side from an opening end edge of air suction port 20a when centrifugal fan 20 is viewed from above. That is, inner periphery-side end portion 23b of each of blades 23 is located inside air suction port 20a beyond the opening end edge of air suction port 20a when viewed from a stacking direction of shroud 21 and hub 22. Specifically, when air suction port 20a is viewed from above, inner periphery-side end portion 23b of each of blades 23 is exposed from air suction port 20a, and a tip of inner periphery-side end portion 23b of each of blades 23 is located inside the opening of air suction port 20a.

[0084] In the present exemplary embodiment, a length (protrusion length) of the portion of each of blades 23 protruding from the opening end edge of air suction port 20a toward the central side is the same in all blades 23. Therefore, a shape formed by connecting the tips of inner periphery-side end portions 23b of blades 23 is circular. Moreover, a virtual circle formed by connecting the tips of inner periphery-side end portions 23b of blades 23 in this manner is concentric with air suction port 20a. A diameter of the virtual circle formed by connecting the tips of inner periphery-side end portions 23b of the plurality of blades 23 is less than or equal to 87% of the diameter of air suction port 20a.

[0085] Specifically, as shown in Fig. 7A, diameter LA of virtual circle A formed by connecting most distal ends of shroud-side portions 23b1 in inner periphery-side end portions 23b of six blades 23 is less than or equal to 87% of diameter LO of air suction port 20a. Also, diameter LB of virtual circle B formed by connecting most distal ends of hub-side portions 23b2 in inner periphery-side end portions 23b of each of six blades 23 is less than or equal to 85% of diameter LO of air suction port 20a. Note that diameter LB of virtual circle B is smaller than diameter LA of virtual circle A and is less than or equal to 85% of diameter LO of air suction port 20a. That is, the most distal ends of hub-side portions 23b2 in inner periphery-side end portions 23b of blades 23 configuring virtual circle B is located closer to the central side than the most distal ends of shroud-side portions 23b1 in inner periphery-side end portions 23b of blades 23 configuring virtual circle A.

[0086] As shown in Figs. 7B and 8, in each of blades 23 erected on the hub 22, at least inner periphery-side end portion 23b is inclined with respect to the main surface (hub surface) of hub 22. In the present exemplary embodiment, in each of the plurality of blades 23, shroud-side portion 23b1 in inner periphery-side end portion 23b is inclined with respect to the stacking direction of shroud 21 and hub 22 so as to be located on a positive side in the rotation direction of centrifugal fan 20 with respect to hub-side portion 23b2.

[0087] In this case, in each of blades 23, an angle formed between a side surface of the hub side portion and the main surface of hub 22 is larger in outer periphery-side end portion 23c than in inner periphery-side end portion 23b. Specifically, as shown in Fig. 8, when an angle (first inclination angle) formed between the side surface of hub-side portion 23b2 and the main surface of hub 22 at an end edge of inner periphery-side end portion 23b of blade 23 is $\theta 1$, and an angle (second inclination angle) formed between a side surface of a hub-side portion and the main surface of hub 22 at an end edge of outer periphery-side end portion 23c of blade 23 is $\theta 2$, $\theta 2 > \theta 1$ is satisfied.

[0088] As one example, in inner periphery-side end portion 23b of each of blades 23, the angle formed by the side surface of hub-side portion 23b2 of inner periphery-side end portion 23b and the main surface of hub 22 is less than or equal to 75 degrees. That is, $\theta 1 \leq 75°$. First inclination angle $\theta 1$ is preferably $65° \leq \theta 1 \leq 70°$. In the present exemplary embodiment, $\theta 1 = 67°$.

[0089] In outer periphery-side end portion 23c of each of blades 23, the side surface of the hub-side portion of outer periphery-side end portion 23c is perpendicular to the main surface of hub 22. That is, outer periphery-side end portion 23c of each of blades 23 is not inclined. Note that in the present specification, "perpendicular" means $90° \pm 2°$ in consideration of manufacturing tolerance and dimensional tolerance. Therefore, $\theta 2 = 90° \pm 2°$.

[0090] Each of blades 23 configured as described above is inclined so that the inclination angle of blade 23 with respect to the main surface of hub 22 gradually increases from outer periphery-side end portion 23c to inner periphery-side end portion 23b. Therefore, in each of blades 23, the inclination angle of the tip of inner periphery-side end portion 23b is the largest, and the inclination angle of the tip of outer periphery-side end portion 23c is the smallest.

[0091] As shown in Fig. 9, when centrifugal fan 20 is viewed from above (i.e., when hub 22 is viewed in a plan view), in an inner periphery-side portion of each of blades 23, assuming that angle $\alpha 1$ (acute angle) formed by a tangent of blade 23 at an arbitrary point on blade 23 and a tangent of the opening end edge of air suction port 20a is defined as an inlet angle, inlet angle $\alpha 1$ is set to a predetermined value. Inlet angle $\alpha 1$ is an angle on a suction side of blade 23 with respect to air suction port 20a.

[0092] In each of blades 23, inlet angle $\alpha 1$ of the inner periphery-side portion of blade 23 is equal to or more than 40 degrees. That is, $\alpha 1 \geq 40°$. An upper limit of inlet angle $\alpha 1$ of the inner periphery-side portion of blade 23 is not particularly limited, but is, for example, 60 degrees. In the present exemplary embodiment, inlet angle $\alpha 1$ of the inner periphery-side portion of blade 23 is 45°.

[0093] In addition, when centrifugal fan 20 is viewed from above, in an outer periphery-side portion of each of blades 23, assuming that angle $\alpha 2$ (acute angle) formed by a tangent of blade 23 at an arbitrary point on blade 23 and a tangent of an outer edge of hub 22 is an outlet angle, outlet angle $\alpha 2$ is set to a predetermined value. Outlet angle $\alpha 2$ is an angle on a blow-out side of blade 23 with respect to hub 22.

[0094] In each of blades 23, outlet angle $\alpha 2$ of the outer periphery-side portion of blade 23 is less than or equal to 40 degree. That is, $\alpha 2 \leq 40°$. In the present exemplary embodiment, inlet angle $\alpha 2$ of the inner periphery-side portion of blade 23 is 25°.

[0095] In each of the plurality of blades 23, an angle (acute angle) formed by a circle concentric with air suction port 20a and having a diameter smaller than the diameter of air suction port 20a and hub-side end surface 23d of relevant blade 23 is larger than inlet angle $\alpha 1$. Specifically, an intersection angle between the concentric circle of air suction port 20a and hub-side end surface 23d of blade 23 gradually increases from an intersection portion between blade 23 and air suction port 20a toward the tip portion of inner periphery-side end portion 23b of blade 23. That is, a radius of curvature of hub-side portion 23b2 of inner periphery-side end portion 23b in each of blades 23 gradually decreases from air suction port 20a toward the tip of inner periphery-side end portion 23b.

[0096] Next, operation and effects of electric blower 1 using centrifugal fan 20 according to the present exemplary embodiment will be described, including a situation where the present disclosure is attained.

[0097] In an electric blower, a centrifugal fan capable of obtaining a high suction pressure is used as a rotary fan for blowing air. As the centrifugal fan, there is a sirocco centrifugal fan of a high air volume and high pressure type. However, a turbo centrifugal fan of a low air volume and high pressure type, which is easily downsized and thinned, is known.

[0098] A turbo centrifugal fan has, for example, a shroud having an air suction port, a hub facing the shroud, and a plurality of blades sandwiched between the shroud and the hub. As each of the blades, a backward blade is used.

[0099] Conventionally, in the centrifugal fan having such a structure, in order to improve performance, it has been proposed that an inner periphery-side end portion of each of the blades protrudes toward a central side from an opening end edge of an air suction port. At this time, if the inner periphery-side end portion of the blade is configured to be substantially perpendicular to the hub, collision loss caused when air sucked from the air suction port collides with the inner periphery-side end portion of the blade increases, and suction pressure decreases. Therefore, the inner periphery-side end portion of the blade is inclined with respect to the hub.

[0100] In this case, in order to obtain a higher suction pressure, it is conceivable to further extend the inner periphery-side end portion of the blade toward the central side of the air suction port. However, when the inner periphery-side end portion of the blade is extended toward the central side, there is a risk that the inner periphery-side end portion of the blade is plastically deformed by centrifugal force when the centrifugal fan rotates.

[0101] At this time, by inclining the inner periphery-side end portion of the blade, not only the collision loss caused by the air colliding with the blade can be suppressed, but also the deformation of the inner periphery-side end portion of the blade due to the centrifugal force can be suppressed to some extent. However, there is a limit to an extension length when the inner periphery-side end portion of the blade is extended toward the central side of the air suction port. That is, even if the inner periphery-side end portion of the blade is extended toward the central side of the air suction port in the inclined state in order to obtain a high suction pressure, the inner periphery-side end portion of the blade is plastically deformed by the centrifugal force. Therefore, there is a limit to extending the inner periphery-side end portion of the blade.

[0102] For example, with respect to a portion of the blade protruding from an opening end edge of the air suction port toward the central side, the length of the hub-side portion is extended toward the central side to a position of substantially 85% of an opening diameter of the air suction port, and a length of a shroud-side portion is extended toward the central side to a position of substantially 90% of the opening diameter of the air suction port. As a result, the inner periphery-side end portion of the blade is plastically deformed by the centrifugal force.

[0103] As a result of intensive studies on such a problem, the present inventors have found that, in the centrifugal fan using the backward blade as the blade, by inclining the inner periphery-side end portion of the blade and increasing the inlet angle on the inner peripheral side of the blade, even if the inner periphery-side end portion of the blade greatly protrudes from the opening end edge of the air suction port toward the central side, the blade can be restrained from being deformed by the centrifugal force. That is, the present inventors have found a structure in which the inner periphery-side end portion of the blade can greatly protrude toward the central side of the air suction port beyond an extension length that has been considered as the limit when the inner periphery-side end portion of the blade is extended.

[0104] Specifically, centrifugal fan 20 used in electric blower 1 according to the present exemplary embodiment has shroud 21 having air suction port 20a, hub 22 facing shroud 21, and the plurality of blades 23 having the shape extending from inner periphery-side end portion 23b to outer periphery-side end portion 23c in the direction opposite to the rotation direction of centrifugal fan 20 and disposed between shroud 21 and hub 22. In each of the plurality of blades 23, inner periphery-side end portion 23b is located inside air suction port 20a when viewed from the stacking direction of shroud 21 and hub 22, and is inclined so that shroud-side portion 23b1 of inner periphery-side end portion 23b is located on the positive side in the rotation direction of centrifugal fan 20 with respect to hub-side portion 23b2, the radius of curvature in the in-plane direction of the main surface of hub 22 in hub-side end surface 23d is larger in outer periphery-side end portion 23c than in inner periphery-side end portion 23b, and the angle between the side surface of hub-side portion 23b2 of inner periphery-side end portion 23b and the main surface of hub 22 is larger in outer periphery-side end portion 23c than in inner periphery-side end portion 23b.

[0105] In the present exemplary embodiment, in centrifugal fan 20 having such a structure, inlet angle $\alpha 1$ in the inner periphery-side portion of blade 23 is set to be equal to or more than 40 degrees. That is, the inlet angle of centrifugal fan 20 is increased. For example, inlet angle $\alpha 1$ can be increased by reducing the radius of curvature of inner periphery-side end portion 23b of blade 23.

[0106] In this regard, in each of the blades of the conventional centrifugal fan, a curve forming the hub-side end surface of the blade has been configured by combining three arcs so that the radius of curvature sequentially decreases from the outer periphery-side end portion to the inner periphery-side end portion. With respect to blade 23 of centrifugal fan 20 in the present exemplary embodiment, as compared with the centrifugal fan configured of these three types of arcs, inlet angle $\alpha 1$ is set to be equal to or more than 40 degrees by further introducing, on the inner peripheral side, an arc having a fourth radius of curvature smaller than the arc having the third radius of curvature to form the curve forming hub-side end surface 23d of blade 23.

[0107] With such a configuration, a strength of the inner periphery-side end portion 23b of blade 23 can be increased structurally. Therefore, a stress acting on inner periphery-side end portion 23b of blade 23 by the centrifugal force can be dispersed. As a result, even if inner periphery-side end portion 23b of blade 23 greatly protrudes from the opening end edge of air suction port 20a toward the central side in order to obtain a high suction pressure, inner periphery-side end portion 23b of blade 23 can be restrained from being compositionally deformed by the centrifugal force.

[0108] Here, the length (protrusion length) of the portion of inner periphery-side end portion 23b of blade 23, the portion protruding from the opening end edge of air suction port 20a toward the central side, has been experimented. A result of the experiment will be described with reference to Fig. 10. Fig. 10 is a diagram showing a relationship between the stress of blade 23 in centrifugal fan 20 according to the exemplary embodiment and the length of the portion protruding from the opening end edge of air suction port 20a toward the central side in inner periphery-side end portion 23b of blade 23 (i.e., the protrusion length of inner periphery-side end portion 23b of blade 23).

[0109] In the present experiment, the stress applied to blade 23 when centrifugal fan 20 was rotated at a high speed of 46,000 [r/min] was found by structural analysis in respective cases where inlet angle α1 of blade 23 on the hub 22 side of centrifugal fan 20 was 34.7 degrees, 41.8 degrees, and 52.6 degrees. At this time, in each of the cases of inlet angle α1, the stress applied to blade 23 was found by changing several protrusion lengths of inner periphery-side end portion 23b of blade 23. Results of the cases are shown in Fig. 10. In the present experiment, centrifugal fan 20 that had an outer diameter of shroud 21 and a diameter of hub 22 of 75 mm, and a diameter of air suction port 20a of shroud 21 of 32 mm, and had six blades 23 was used. As blade 23, an aluminum plate made of aluminum and having a plate thickness of 0.6 mm was used.

[0110] Here, from a viewpoint of a tensile strength of an aluminum material, a region where the stress of blade 23 exceeds 300 [MPa], are a region where blade 23 is plastically deformed.

[0111] Therefore, as shown in Fig. 10, in the case where inlet angle α1 is 34.7 degrees, it can be seen that the stress of blade 23 exceeds 300 [MPa] at least when the protrusion length of blade 23 becomes 5.8 [mm]. That is, when inlet angle α1 is 34.7 degrees, the protrusion length of blade 23 cannot be made longer than 5.8 [mm], and from Fig. 10, the protrusion length of blade 23 can be made long only up to about 5 [mm].

[0112] In the case where inlet angle α1 is 41.8 degrees, it can be seen that the stress of blade 23 exceeds 300 [MPa] at least when the protrusion length of blade 23 is 8 [mm]. From Fig. 10, in the case where inlet angle α1 is 41.8 degrees, the protrusion length of blade 23 can be increased up to about 7.5 [mm]. In this case, the diameter of the virtual circle formed by connecting the tips of inner periphery-side end portions 23b of the plurality of blades 23 is less than or equal to 87% of the diameter of air suction port 20a on the shroud 21 side. Further, inner periphery-side end portion 23b of each of the plurality of blades 23 can be extended to the central side up to a position where the diameter of the virtual circle on the hub 22 side becomes less than or equal to 85% of the diameter of air suction port 20a.

[0113] In this way, by setting inlet angle α1 to be equal to or more than 40 degrees, the length of the portion of inner periphery-side end portion 23b of blade 23, the portion protruding from the opening end edge of air suction port 20a toward the central side, can be greatly extended. As a result, even if the length of hub-side portion 23b2 in inner periphery-side end portion 23b of blade 23 is extended to the central side to the position less than or equal to 85% of the opening diameter of air suction port 20a, blade 23 can be prevented from being deformed by the centrifugal force.

[0114] Note that as shown in Fig. 10, in the case where inlet angle α1 is 52.6 degrees, it is considered that the stress of blade 23 does not exceed 300 [MPa]. That is, in the case where inlet angle α1 is 52.6 degrees, in principle, the protrusion length of blade 23 can be maximized until the plurality of blades 23 come into contact with one another at the center of air suction port 20a. However, in the case where inlet angle α1 exceeds 50 degrees, it is structurally difficult to reduce the radius of curvature of the curve forming the hub-side end surface 23d with a structure in which inner periphery-side end portion 23b of blade 23 remains inclined with respect to hub 22. Therefore, inlet angle α1 is preferably less than or equal to 50 degrees.

[0115] As described above, according to electric blower 1 of the present exemplary embodiment, even if the length of hub-side portion 23b2 in inner periphery-side end portion 23b of blade 23 is extended to the central side up to the position less than or equal to 85% of the opening diameter of air suction port 20a, inner periphery-side end portion 23b of blade 23 can be restrained from being deformed by the centrifugal force. Moreover, by inclining inner periphery-side end portion 23b of blade 23 with respect to hub 22, not only deformation of blade 23 can be suppressed, but also collision loss caused when the air sucked from air suction port 20a collides with inner periphery-side end portion 23b of blade 23 can be suppressed. This allows a higher suction pressure to be obtained. Therefore, it is possible to easily obtain an electric blower having a high suction pressure equivalent to that of a centrifugal fan in the case where an inducer is provided.

[0116] As described above, according to electric blower 1 of the present exemplary embodiment, it is possible to suppress deformation of the blade due to the centrifugal force and to obtain a high suction pressure without providing the inducer.

[0117] Moreover, in electric blower 1 according to the present exemplary embodiment, as described above, the diameter of the virtual circle formed by connecting the tips of inner periphery-side end portions 23b of the plurality of blades 23 is less than or equal to 85% of the diameter of air suction port 20a on the hub 22 side. The diameter of the virtual circle is less than or equal to 87% of the diameter of air suction port 20a on the shroud 21 side.

[0118] As a result, inner periphery-side end portion 23b of inclined blade 23 can protrude more greatly toward the central side than the opening end edge of air suction port 20a, so that electric blower 1 that can bring about a higher suction pressure can be realized.

[0119] Moreover, in electric blower 1, in each of the plurality of blades 23, the angle formed by the circle concentric with air suction port 20a and having a diameter smaller than the diameter of air suction port 20a, and hub-side end surface 23d of blade 23 is larger than inlet angle α1.

[0120] With this configuration, the radius of curvature can be reduced up to the tip of inner periphery-side end portion 23b of inclined blade 23. Thus, even if inner periphery-side end portion 23b of blade 23 more greatly protrudes toward the central side, inner periphery-side end portion 23b of blade 23 can be restrained from being deformed, so that electric blower 1 that can bring about a higher suction pressure can be realized.

[0121] In addition, in electric blower 1, in each of the plurality of blades 23, the angle formed between the side surface of hub-side portion 23b2 of inner periphery-side end portion 23b and the main surface of hub 22 is less than or equal to 75 degrees, and the side surface of the hub side portion of outer periphery-side end portion 23c is perpendicular to the main surface of hub 22.

[0122] With this configuration, it is possible to further suppress the deformation of inner periphery-side end portion 23b of blade 23 due to the centrifugal force.

[0123] In addition, in electric blower 1, in each of the plurality of blades 23, outlet angle $\alpha 2$ of the outer periphery-side portion is less than or equal to 40 degrees.

[0124] With this configuration, it is possible to realize electric blower 1 capable of obtaining a higher suction pressure.

[0125] Moreover, in electric blower 1, when centrifugal fan 20 is viewed from above, air suction port 20a is circular, and the diameter of the virtual circle formed by connecting the tips on the hub 22 side of inner periphery-side end portions 23b of the plurality of blades 23 is smaller than the diameter of the virtual circle formed by connecting the tips on the shroud 21 side of inner periphery-side end portions 23b of the plurality of blades 23.

(Modifications)

[0126] While electric blower 1 according to the present disclosure has been described above based on the exemplary embodiment, the present disclosure is not limited to the above-described exemplary embodiment.

[0127] For example, while in the above-described exemplary embodiment, the commutator motor with the brushes is used as electric motor 10 employed in electric blower 1, electric motor 10 is not limited thereto. Electric motor 10 may be a brushless motor or the like.

[0128] Moreover, while in the above-described exemplary embodiment, electric motor 1 is described in the case of being used for a vacuum cleaner, the present disclosure is not limited thereto. For example, electric blower 1 may be used for another electric apparatus such as an air towel.

[0129] In addition, the present disclosure also includes a mode obtained by applying various modifications conceived by those skilled in the art to the above-described exemplary embodiment, or a mode achieved by arbitrarily combining components and functions in the exemplary embodiment without departing from the gist of the present disclosure.

INDUSTRIAL APPLICABILITY

[0130] The technology of the present disclosure can be used for various electric apparatuses each using an electric blower. The technology of the present disclosure is particularly useful for an electric blower mounted on a vacuum cleaner or the like in which a fan is rotated at high speed.

REFERENCE MARKS IN THE DRAWINGS

[0131]

1: electric blower
10: electric motor
11: rotor
11a: rotary shaft
11b: rotor core
11c: winding coil
12: stator
13: first bearing
14: second bearing
15: commutator
16: brush
20: centrifugal fan
20a, 50a: air suction port
20b, 70b: exhaust port
21: shroud
21a, 22a, 22b: through hole
22: hub
23, 23A: blade
23a1: first protruded portion
23a2: second protruded portion
23b: inner periphery-side end portion
23b1: shroud-side portion
23b2: hub-side portion
23c: outer periphery-side end portion
23d: hub-side end surface
30: fixing member
31: fan boss
32: first abutting plate
33: second abutting plate
34: fan stopper
40: air guide
41: diffuser blade
50: fan case
51: lid portion
52: side wall portion
60: fan case spacer
70: motor case
70a: opening portion
80: bracket

Claims

1. An electric blower comprising:

a rotor having a rotary shaft; and
a centrifugal fan attached to the rotary shaft, the centrifugal fan including:

a shroud having an air suction port;

a hub facing the shroud; and
a plurality of blades each having a shape extending in a direction opposite to a rotation direction of the centrifugal fan from an inner periphery-side end portion to an outer periphery-side end portion, the plurality of blades being disposed between the shroud and the hub,

wherein
in each of the plurality of blades,

the inner periphery-side end portion is located inside the air suction port when viewed from a stacking direction of the shroud and the hub, and is inclined to locate a shroud-side portion of the inner periphery-side end portion on a positive side of the rotation direction with respect to a hub-side portion,
a radius of curvature in an in-plane direction of a main surface of the hub in an end surface on a hub side is larger in the outer periphery-side end portion than in the inner periphery-side end portion,
an angle formed by a side surface of the hub-side portion and the main surface of the hub is larger in the outer periphery-side end portion than in the inner periphery-side end portion, and
an inlet angle in an inner periphery-side portion is equal to or more than 40 degrees.

2. The electric blower according to claim 1, wherein the air suction port is circular when the centrifugal fan is viewed from above, and a diameter of a virtual circle formed by connecting tips of the inner periphery-side end portions of the plurality of blades is less than or equal to 87% of a diameter of the air suction port.

3. The electric blower according to claim 1 or claim 2, wherein the air suction port is circular when the centrifugal fan is viewed from above, and in each of the plurality of blades, an angle formed by a circle concentric with the air suction port and having a diameter smaller than the diameter of the air suction port, and the end surface of the blade on the hub side is larger than the inlet angle.

4. The electric blower according to any one of claims 1 to 3, wherein in each of the plurality of blades, the angle formed by the side surface of the hub-side portion in the inner periphery-side end portion and the main surface of the hub is less than or equal to 75 degrees, and the side surface of the hub-side portion in the outer periphery-side end portion is perpendicular to the main surface of the hub.

5. The electric blower according to any one of claims 1 to 4, wherein in each of the plurality of blades, an outlet angle of the outer periphery-side portion is less than or equal to 40 degrees.

6. The electric blower according to any one of claims 2 to 5, wherein the air suction port is circular when the centrifugal fan is viewed from above, and a diameter of a virtual circle formed by connecting tips on the hub side of the inner periphery-side end portions of the plurality of blades is smaller than a diameter of a virtual circle formed by connecting tips on the shroud side of the inner periphery-side end portions of the plurality of blades.

FIG. 1

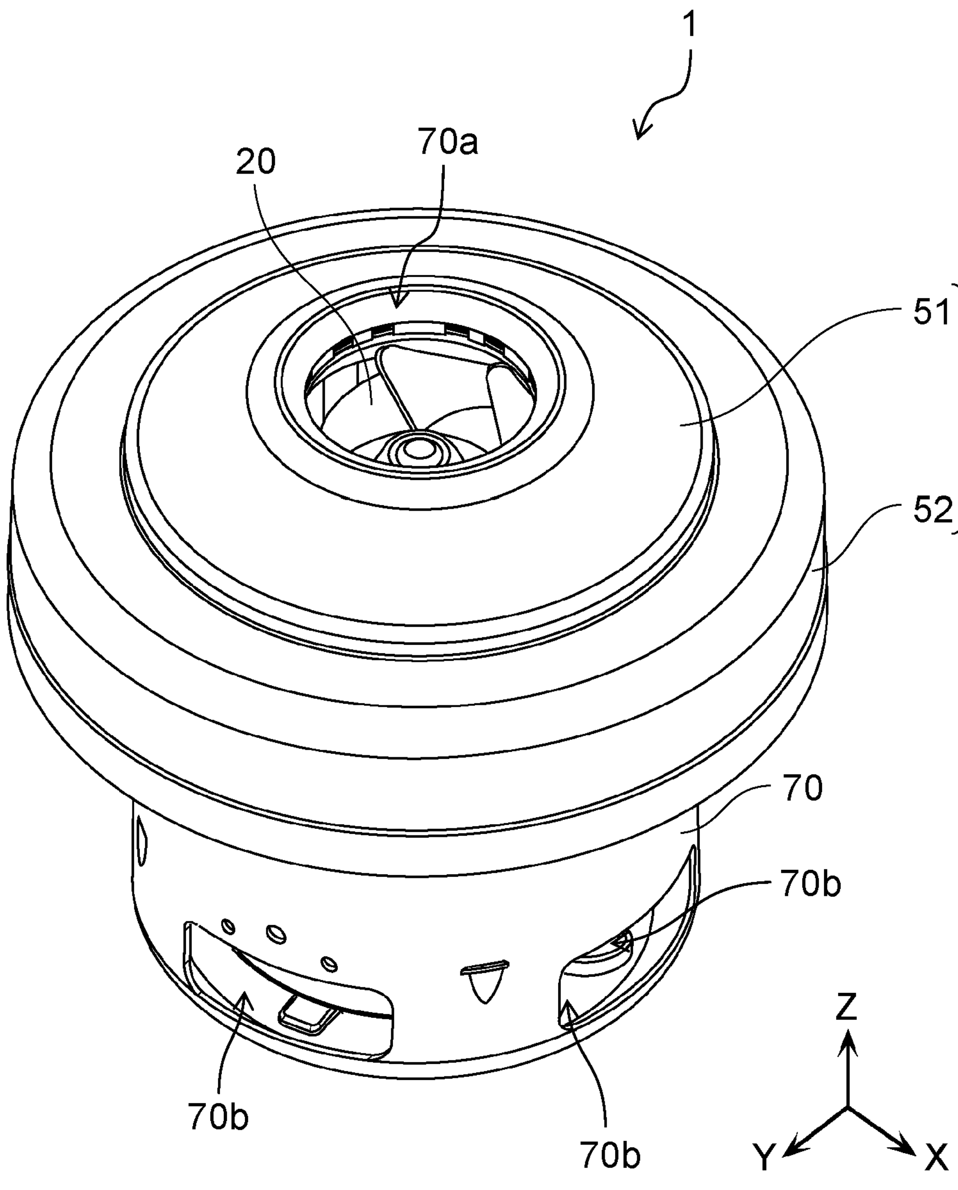


FIG. 2

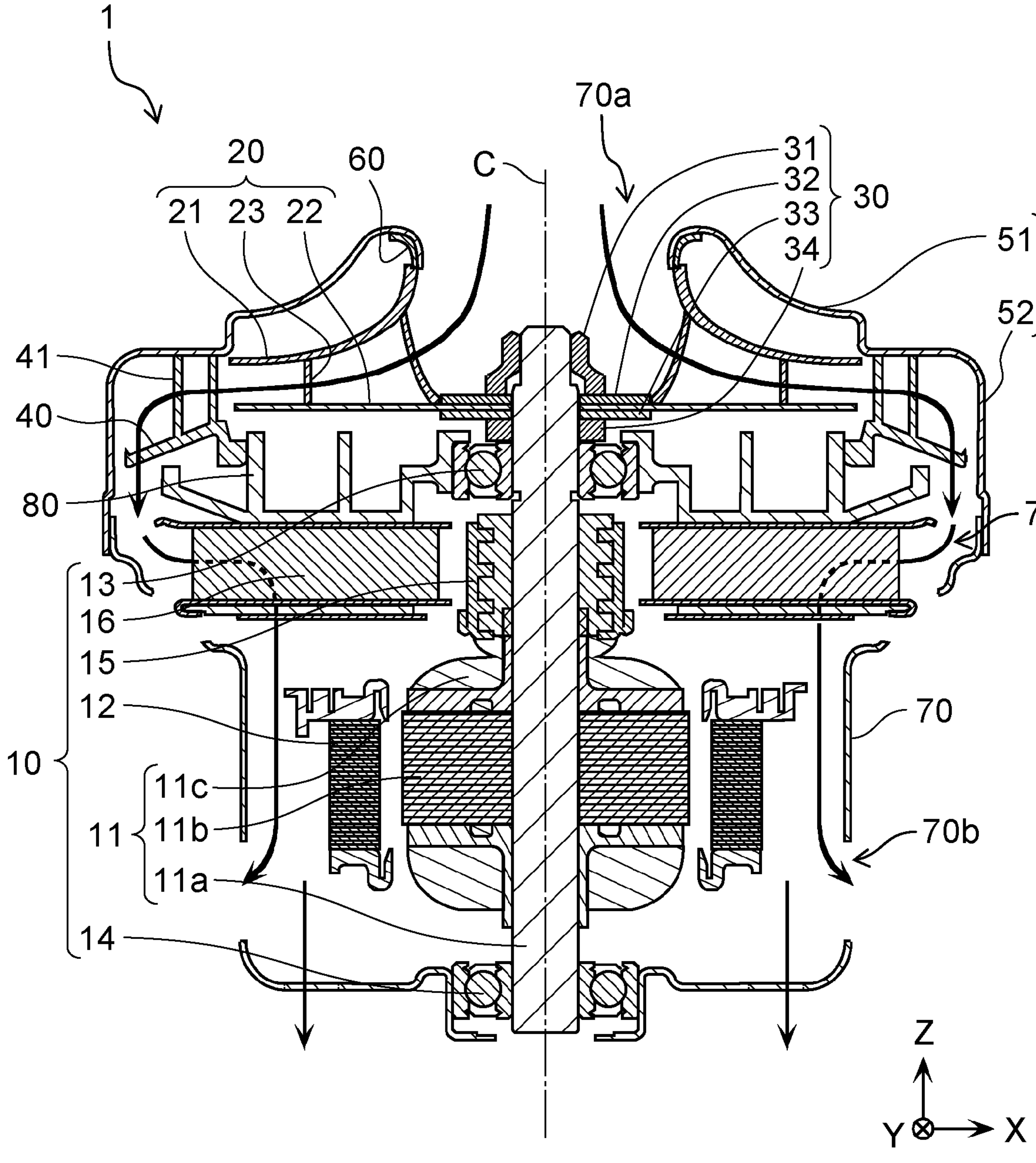

1
20
21
23
22
60
C
70a
31
32
33
34
30
51
52
50
41
40
80
70a
13
16
15
12
10
11c
11b
11
11a
14
70
70b
Z
Y
X

FIG. 3

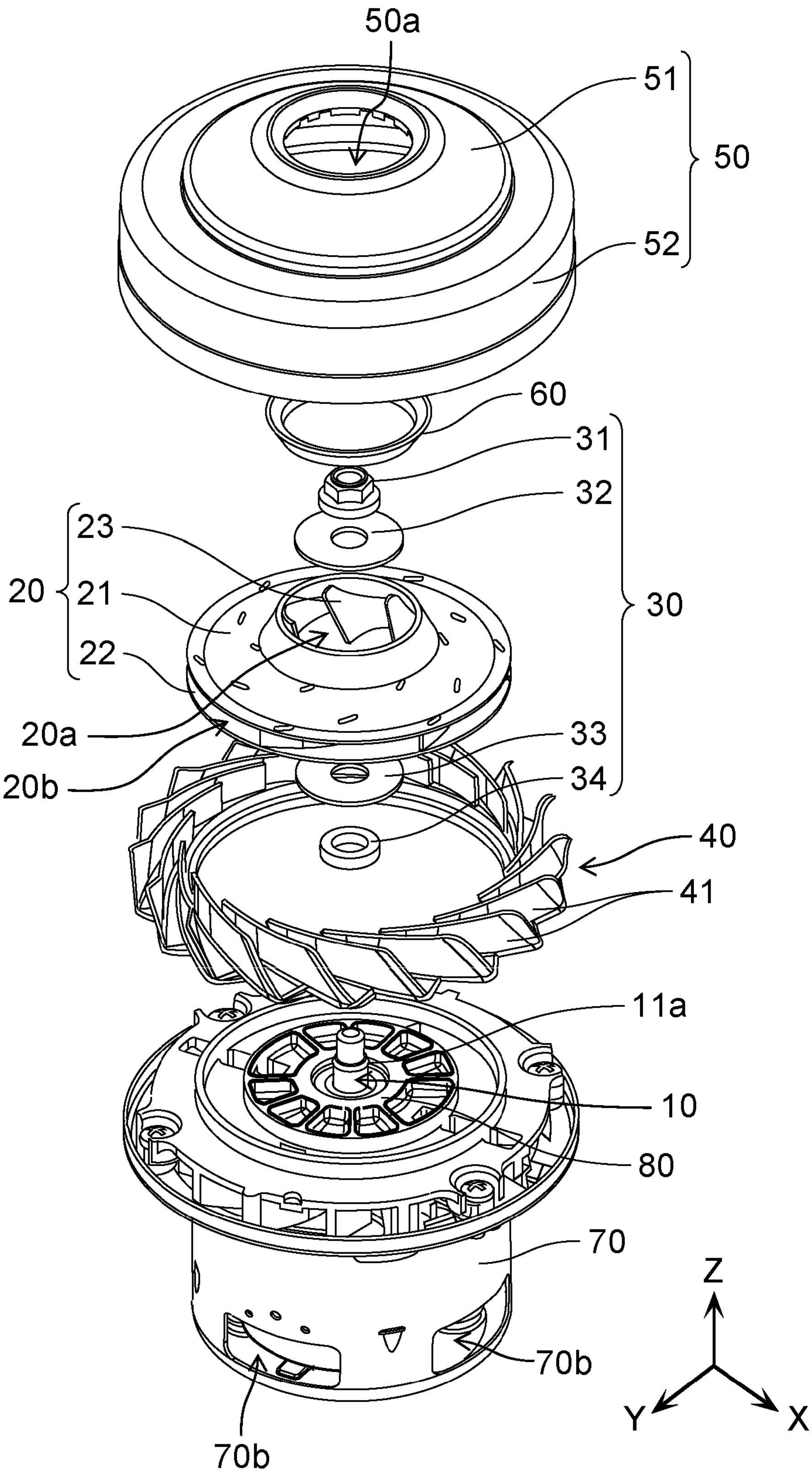

50a
51
50
52
60
31
32
30
23
20
21
22
20a
20b
33
34
40
41
11a
10
80
70
Z
70b
Y
X
70b

FIG. 4

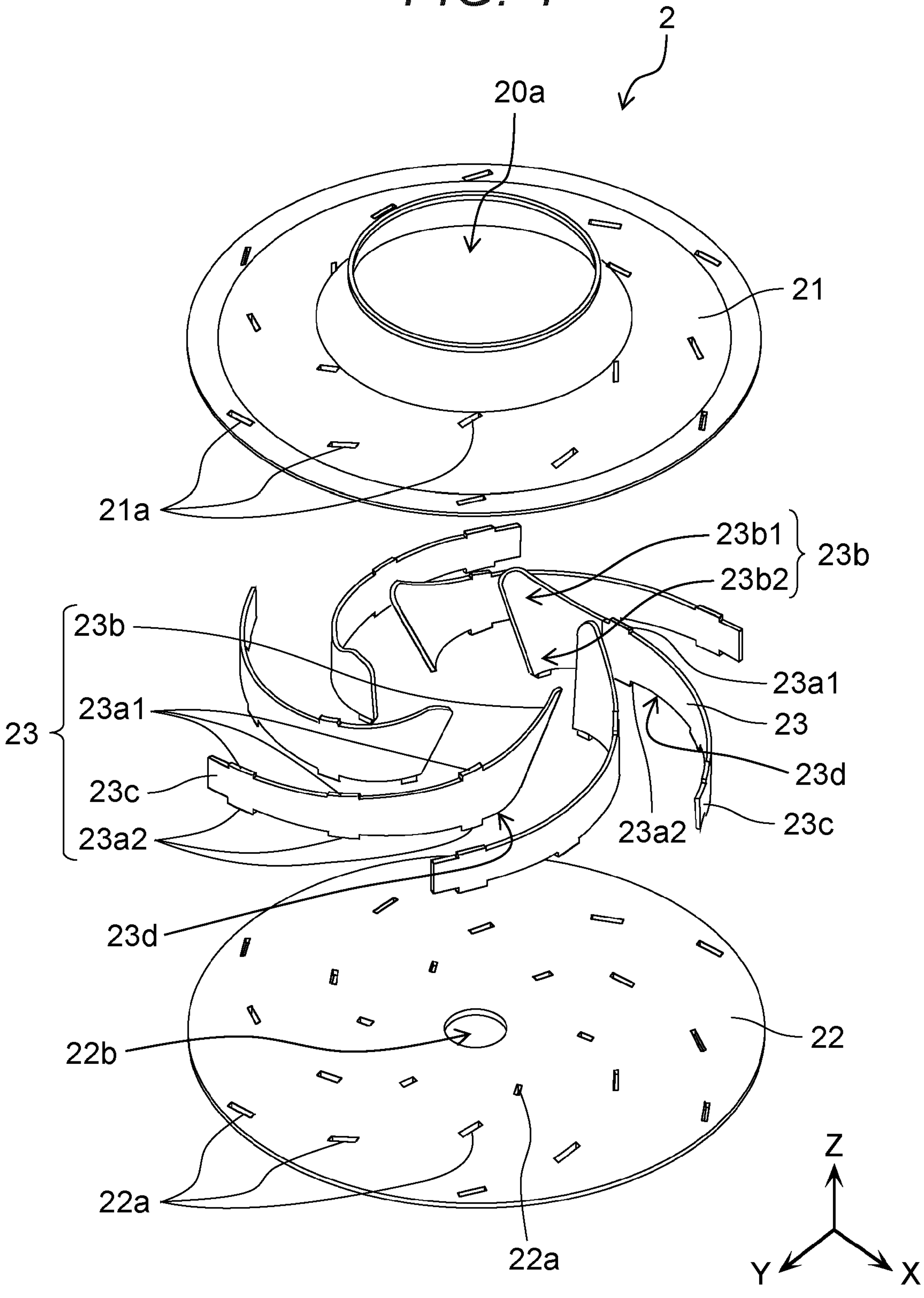

2
20a
21
21a
23b1
23b2
23b
23b
23a1
23
23c
23a2
23a1
23
23d
23c
23a2
23d
22b
22
22a
22a
Z
Y
X

FIG. 5

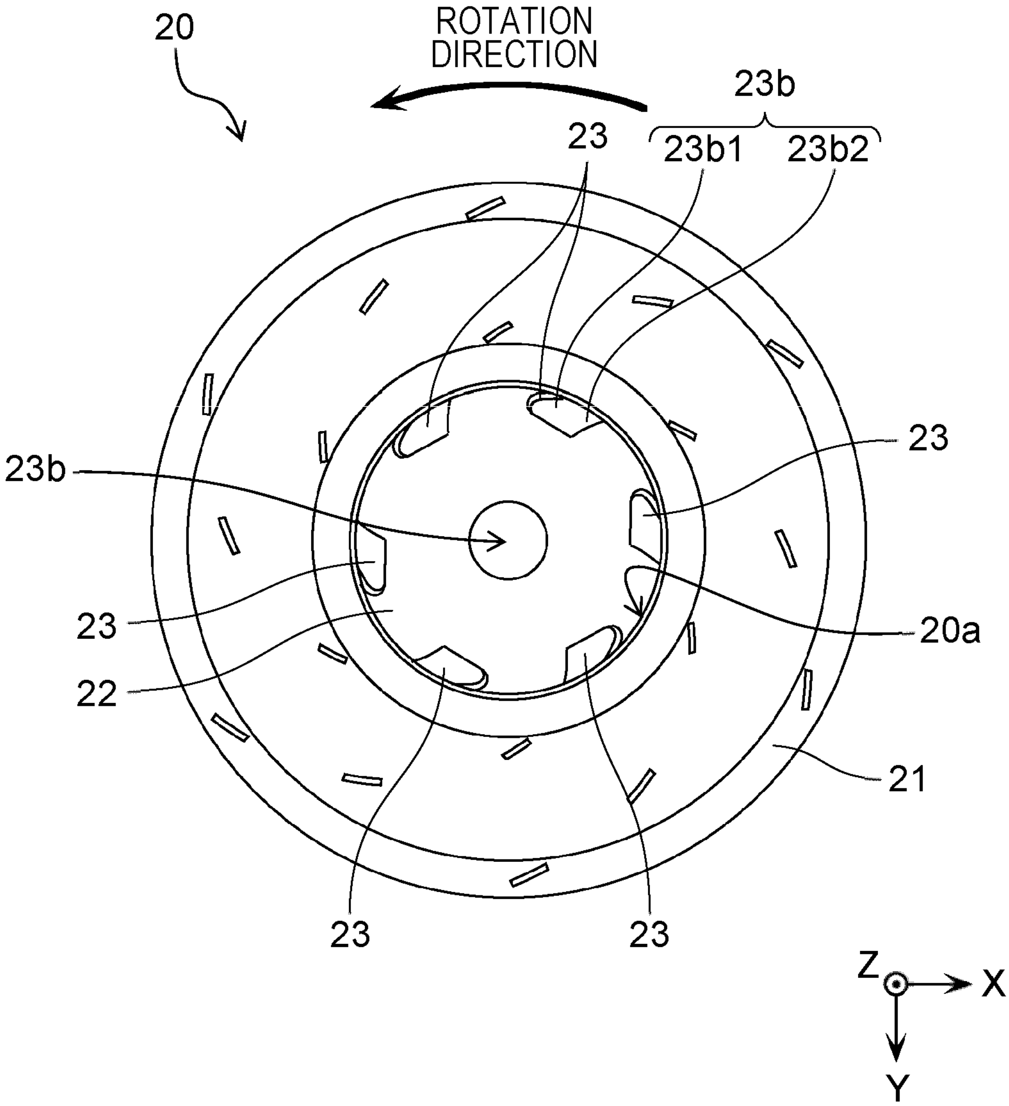

20
ROTATION
DIRECTION
23b
23
23b1
23b2
23
23b
23
20a
22
21
23
23
Z
X
Y

FIG. 6

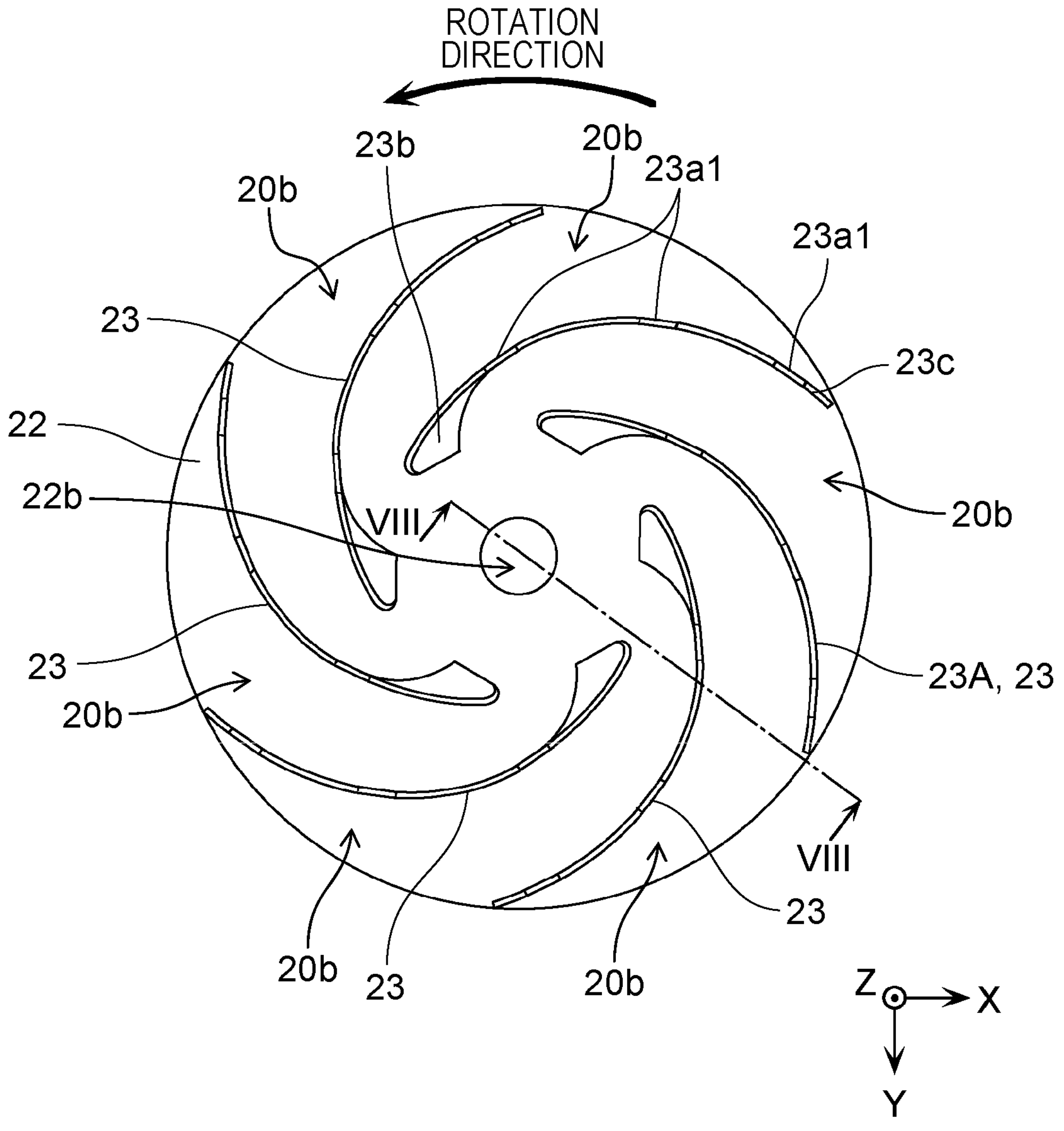

ROTATION
DIRECTION
23b
20b
23a1
20b
23a1
23
23c
22
20b
22b
VIII
23A, 23
23
20b
VIII
23
20b
23
20b
Z
X
Y

FIG. 7A

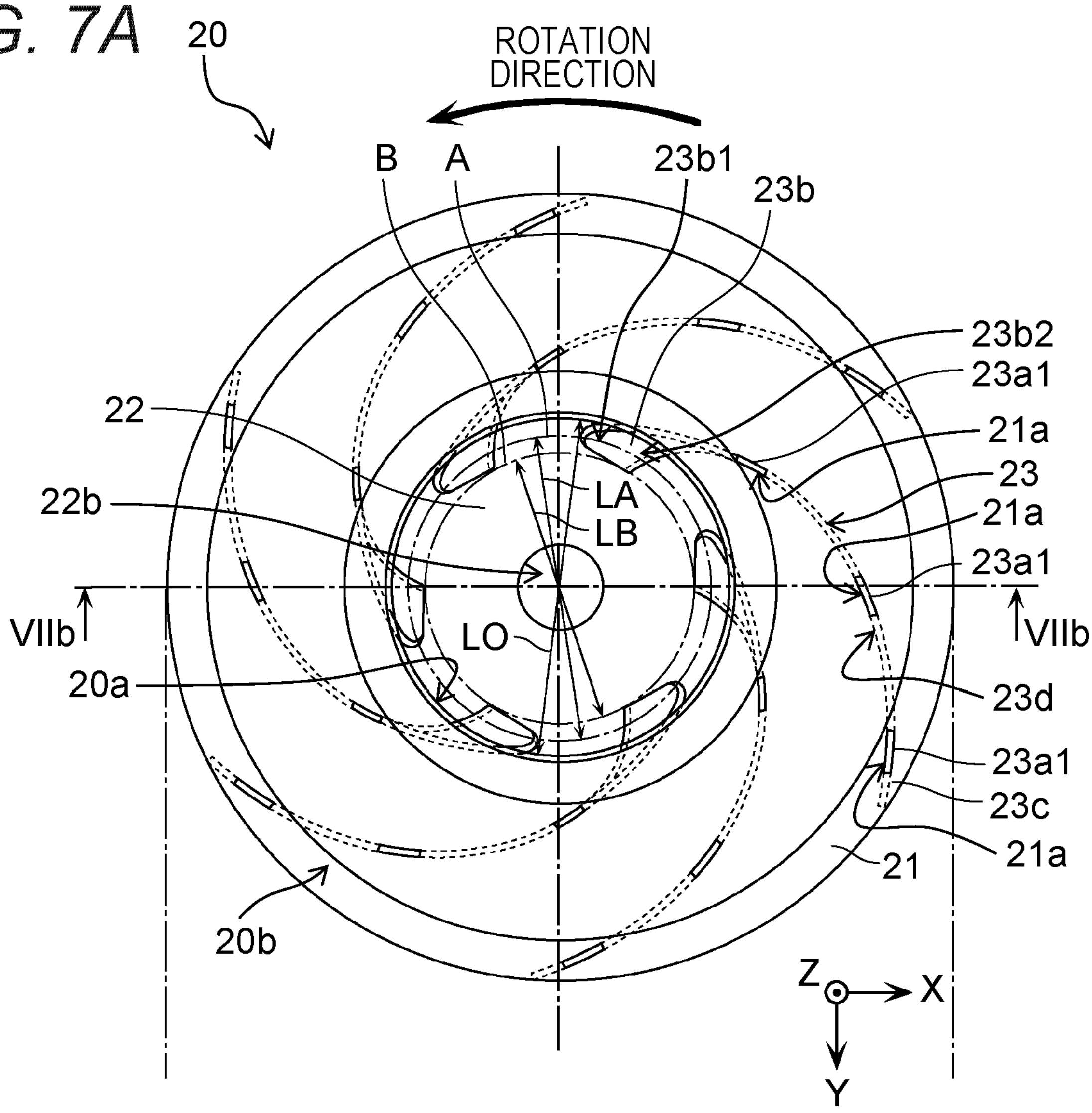

20
ROTATION
DIRECTION
B
A
23b1
23b
23b2
23a1
22
21a
23
22b
LA
LB
21a
23a1
VIIb
VIIb
LO
20a
23d
23a1
23c
21a
21
20b
Z
X
Y

FIG. 7B

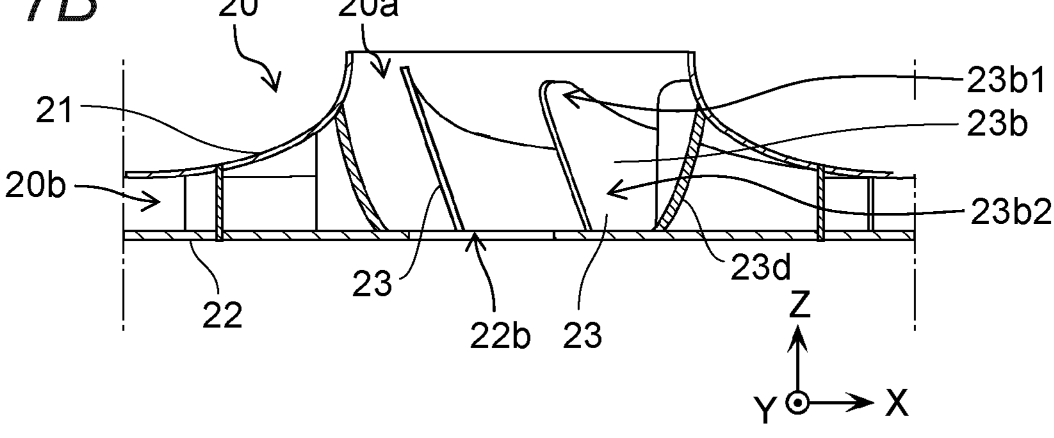

20
20a
23b1
21
23b
20b
23b2
23d
23
22
22b
23
Z
Y
X

FIG. 8

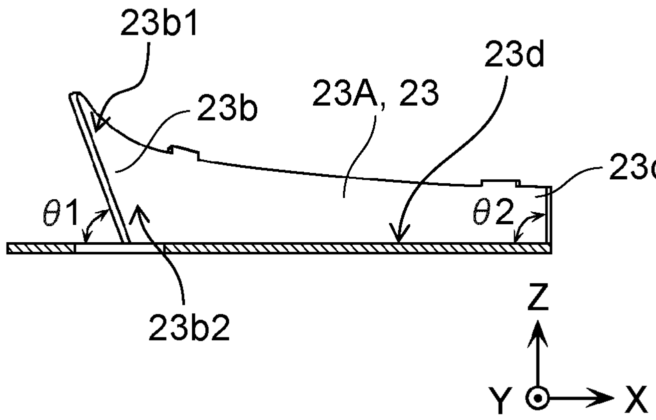

23b1
23b
23A, 23
23d
23c
θ1
θ2
23b2
Z
Y
X

FIG. 9

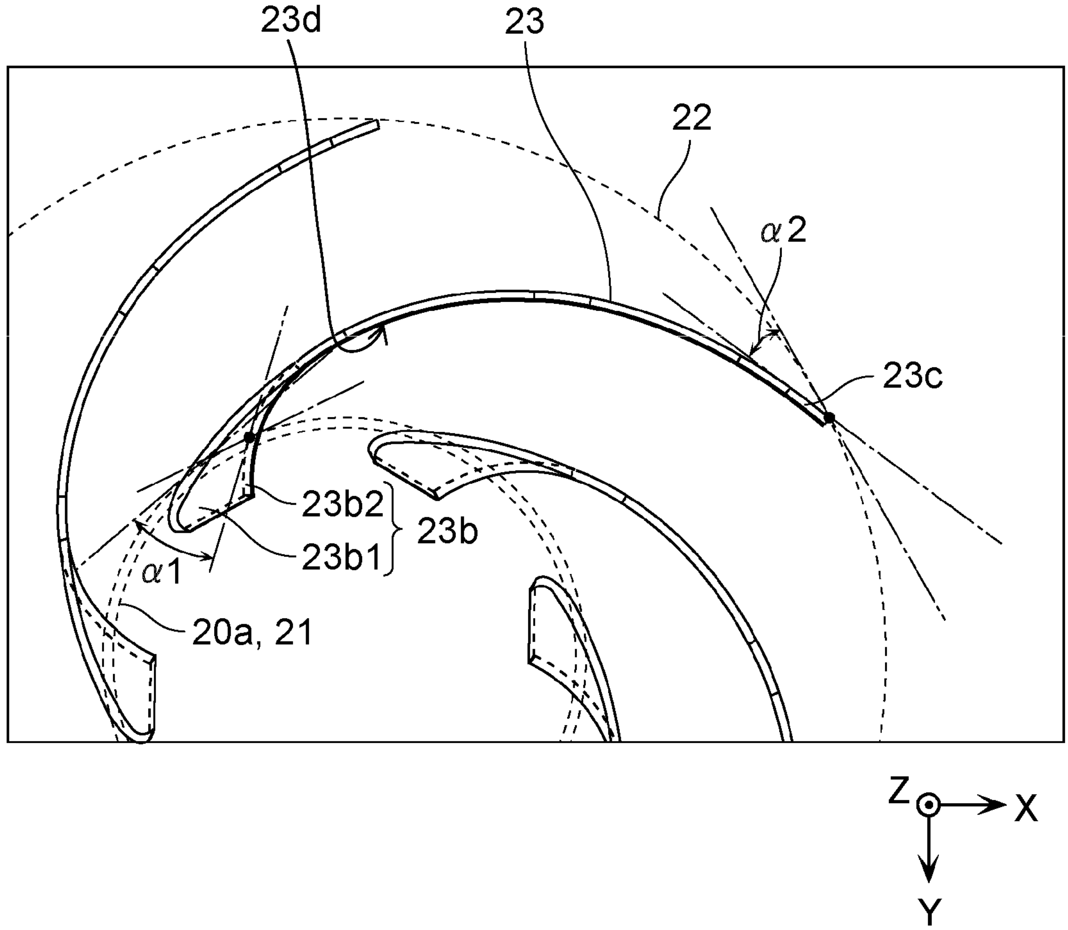

23d
23
22
α2
23c
23b2
23b
23b1
α1
20a, 21
Z
X
Y

FIG. 10

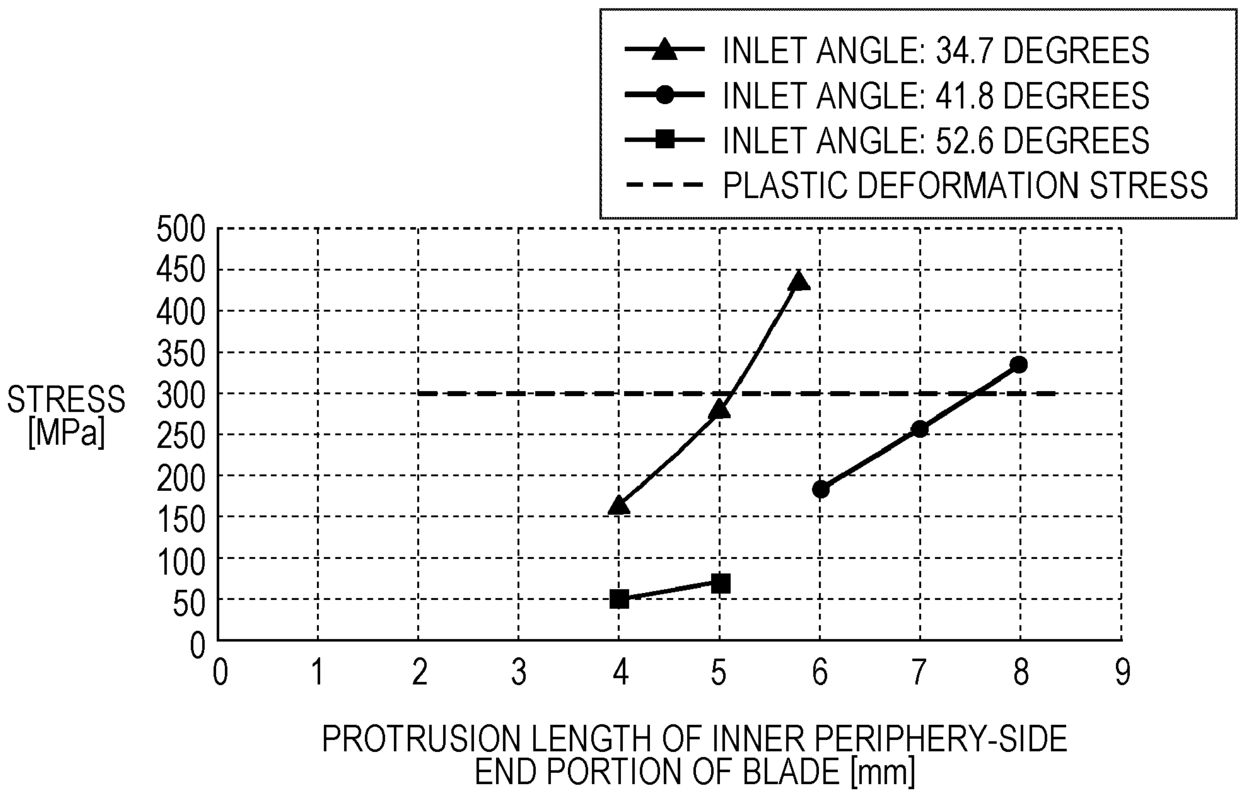

INLET ANGLE: 34.7 DEGREES
INLET ANGLE: 41.8 DEGREES
INLET ANGLE: 52.6 DEGREES
PLASTIC DEFORMATION STRESS
STRESS [MPa]
500
450
400
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
PROTRUSION LENGTH OF INNER PERIPHERY-SIDE END PORTION OF BLADE [mm]

FIG. 11A

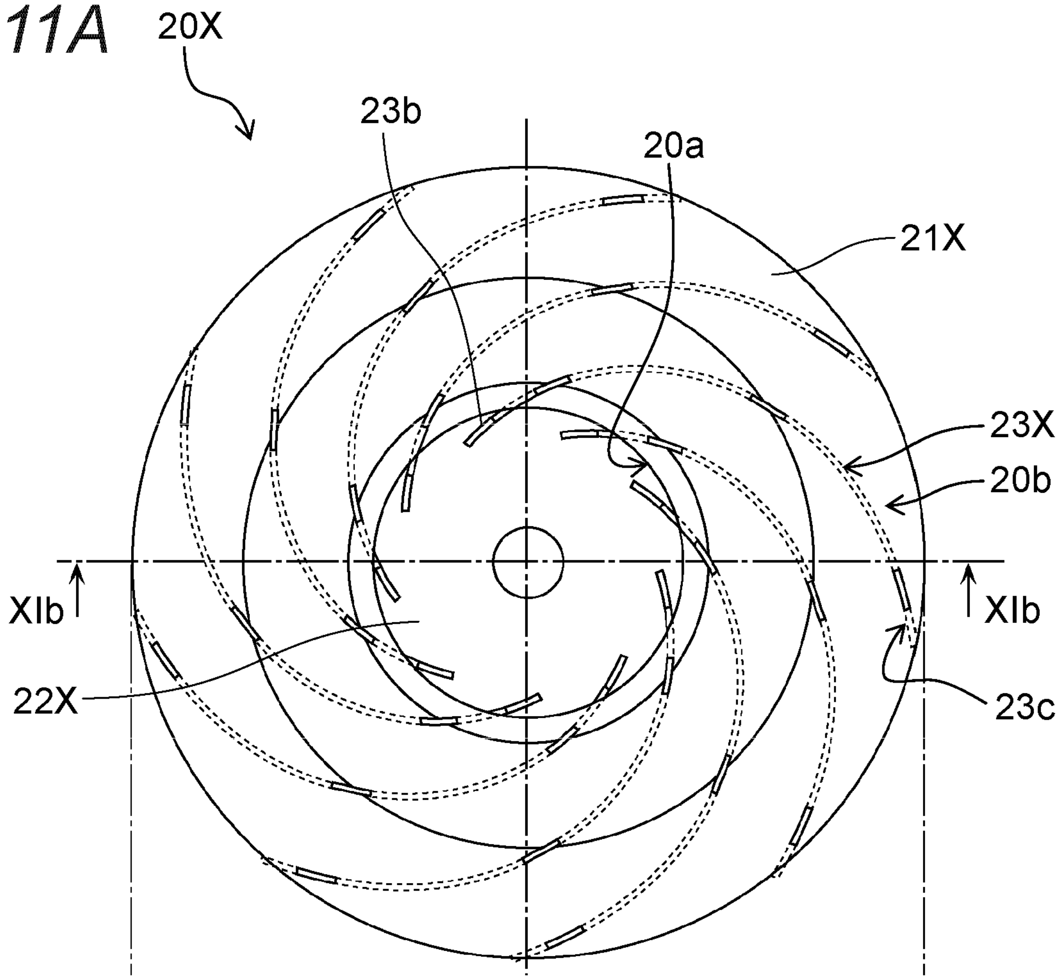
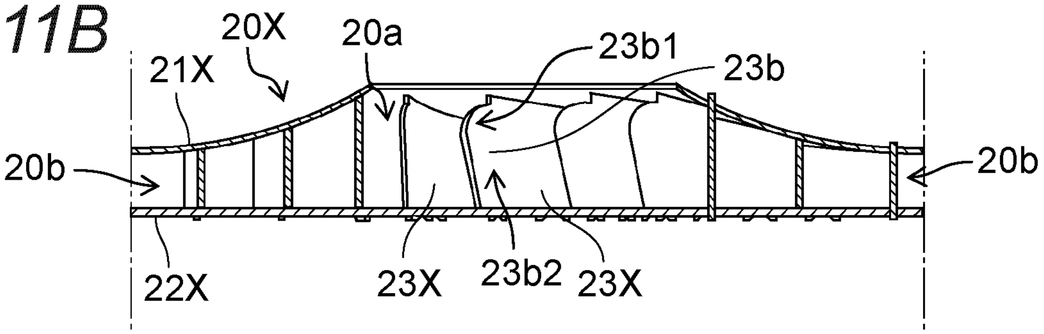


FIG. 11B



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2021/004501

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F04D29/28(2006.01)i, F04D29/30(2006.01)i
FI: F04D29/30 C, F04D29/28 C

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. F04D29/28, F04D29/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2011-226398 A (HITACHI APPLIANCES, INC.) 10 November 2011, paragraphs [0030]-[0036], [0038], [0040], [0041], fig. 1, 2, 4, 5	1-6
A	WO 2017/154151 A1 (MITSUBISHI ELECTRIC CORP.) 14 September 2017, entire text, drawings	1-6

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01.04.2021	13.04.2021

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/004501

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
JP 2011-226398 A	10.11.2011	CN 102235384 A paragraphs [0102]-[0108], [0110], [0112], [0113], fig. 1, 2, 4, 5	
WO 2017/154151 A1	14.09.2017	TW 201732155 A entire text, drawings	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2757501 B **[0013]**
- JP 3796974 B **[0013]**