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(54) TURBOFAN AND AIR CONDITIONER

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Description

Technical Field

[0001] The present invention relates to a turbofan and an air conditioning apparatus, and more particularly, to a turbofan for use in an air conditioning apparatus for air cleaning, humidifying, dehumidifying, cooling, or heating purposes and to an air conditioning apparatus provided with the same.

Background Art

[0002]

(A) A turbofan having a fan blade formed in a three-dimensional shape is widely used for a blower fan to be mounted on a conventional ceiling-embedded type air conditioning apparatus.

For example, there is disclosed a turbofan having a blade inlet diameter gradually increasing toward a side plate side from a main plate side, having an inlet diameter at a blade side plate inside end being greater than an inlet diameter of a side plate and having a blade upper end slanted in a rotational direction of an impeller, and a turbofan in which an inclination angle between the impeller rotational axis and the blade upper end is set at a greater angle at a position closer to the impeller outer circumference than to the impeller inner circumference, while the inclination angle is set at a smaller angle in the vicinity of the side plate, in a cross-sectional view as taken in the shape of a cylinder concentric with the impeller axis (see Patent Document 1, for example).

The turbofan according to this arrangement prevents an air flow from a blade upper end from separating on a blade negative-pressure surface as well as prevents degradation in air blowing performance and an increase in noise level due to turbulent flow.

(B) Also, as another conventional example, there is disclosed a turbofan in which the position of a side plate side jointed portion of a blade trailing edge is offset from a main plate side jointed portion in an opposite impeller rotational direction by a predetermined distance, and at the same time the position of a side plate side jointed portion of a blade leading edge is offset from the main plate side jointed portion in an impeller rotational direction by a predetermined distance (see Patent Document 2, for example).

The turbofan according to this arrangement allows a blade pressure surface to be tilted toward the side plate side at the blade trailing edge, which causes a force exerted by the pressure surface on the air to lean against the side plate, preventing air flow separation on the outlet side of the side plate. In addition, it elongates a blade chord length on the blade side plate side having a greater flow speed at the blade leading edge, which causes the air flow entering to

the blade leading edge near the main plate to head on the side plate side and prevents separated flow from occurring on the side of the outlet of the blade side plate, thereby homogenizing wind speed distribution on the front face side of the heat exchanger disposed downstream of the impeller in the entire vertical region.

(C) Furthermore, there are disclosed a turbofan having a joined end with the side plate shifted in the rotational direction in relation to a joined end with the main plate in a region from the leading edge to the trailing edge, and having the side plate end on the blade leading edge side slanted toward the rotational direction, a turbofan having the side plate end on the blade leading edge side slanted radially inward in the rotational direction with a greater inclination angle (inlet angle α) on the center side than on the main and side plate sides or a smaller inclination angle at on the side plate side than on the main plate side, and a turbofan having the side plate end at the blade trailing edge slanted radially outward in the opposite rotational direction with a greater inclination angle (outlet angle β) on the center side than on the main and side plate sides (see Patent Document 3, for example).

[0003] The turbofans according to these arrangements cause the side plate side end of the blade leading edge having a particularly greater velocity component in the axial direction of inlet air to be slanted in the rotational direction so as to follow the air inlet direction, thereby securely preventing a separation forming readily in the opposite blade rotational direction and consequently providing improved performance and reduced noise levels. Also, a greater leading edge side inclination angle α at the center allows air to be very smoothly taken in from the inner circumferential side. Furthermore, if an inclination angle α on the side plate side is smaller than that on the main plate side, air can be smoothly taken in since the blade is shaped to follow the inlet angle. At the blade trailing edge, a greater inclination angle (outlet angle β) on the center side than on the main and side plate sides allows homogenization of air blown on the outer circumferential side.

[0004]

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 10-30590 (page 4, Fig. 8)

[Patent Document 2] Japanese Patent No. 2701604 (page 4, Fig. 3)

[Patent Document 3] Japanese Patent No. 3861008 (page 7, Fig. 4)

Disclosure of Invention

Problems to be solved by the Invention

[0005] However, a turbofan and an air conditioning ap-

paratus disclosed in Patent Documents 1 to 3 have the following problems.

(A) A turbofan disclosed in Patent Document 1 has a difficulty in assembly. That is, at least in the case of a turbofan in which an impeller is integrally formed after molding a blade and a side plate separately and joining them into one unit by welding or fitting, if a blade upper end is slanted in the impeller rotational direction, such a slanted upper end causes a stress to be exerted on the main plate joined portion, so as to prevent a force from being properly applied to the side plate, because the side plate and the blade are joined by pressing the side plate on the blade in the direction of the rotational axis.

(B) In a case of forming of a thermoplastic resin, there is a problem of an increase in weight due to increasing amount of materials and poor workability. That is, forming of a thermoplastic resin may cause a surface sink, leading to poor workability. Since a thickness of a blade with poor workability is substantially equal along the impeller height direction from the main plate to the side plate, in a case of wing type blade in which the thickness of the blade gradually increases from the impeller inner circumference in a plan view perpendicular to the rotational axis and further decreases toward the impeller outer circumference, in the vicinity of the center of the blade having a larger thickness, for example, the thickness increases at the slanted blade upper edge in a side view resulting in increased amount of materials used, resultant increased weight, and occurrence of a surface sink.

(C) In addition, an inclination angle at the blade upper edge is increased at least toward the impeller outer circumference from the inner circumference so that the amount of inflow air at the blade side plate joined portion increases and as a result interferes with air flow from the blade impeller inner circumference of the blade, causing noise or vibration which degrades ambient surroundings (hereinafter called "degraded noise problem").

(D) In a turbofan disclosed in Patent Document 2, the side plate side joined portion of the blade trailing edge is offset by a predetermined amount in the opposite rotational direction from the main plate side joined portion, which improves the homogenization of wind speed distribution on the front face side of the heat exchanger disposed downstream of the impeller, but causes air flow to concentrate on the side plate side at the blade trailing edge in the impeller outlet, leading to a degraded noise problem.

(E) Offsetting the side plate side joined portion of the blade leading edge by a predetermined amount in the rotational direction from the main plate side joined portion prevents a separation around the side plate side joined portion, but a separation in a region from the intermediate portion of the blade leading

edge to the blade side, plate side joined portion still remains unchanged, so that there is room for noise reduction.

(F) Furthermore, the blade side plate side joined portion is slanted in the rotational direction in relation to the main plate side joined portion, and the surface of the main plate and the blade pressure surface (surface of the opposite rotational direction) make a sharp angle of less than 90 degrees. This causes an inlet air flow from the leading edge to drift into the main plate side, leaving a separation region in the blade trailing edge at the side plate side.

(G) In addition, offsetting the blade side plate side joined portion on the sides of the leading and trailing edges in the reverse direction causes a region from the blade side plate side joined portion joined to the side plate to the main plate side joined portion to be slanted relative to the side plate, which leads to a difficulty in assembly, like a turbofan disclosed in Patent Document 1.

(H) Meanwhile, in a turbofan disclosed in Patent Document 3, the side plate side joined portion is shifted over a portion from the blade leading edge to the trailing edge in the rotational direction in relation to the main plate side joined portion, and the side plate side end on the leading edge side is slanted in the rotational direction, which prevents separation of an inlet air flow at the side plate side end and the side plate side joined portion, but causes an inlet air flow from the leading edge to drift on the main plate side, leaving a separation region in the blade trailing edge on the side plate side.

(I) In the case of a turbofan formed by at least molding a blade and a side plate separately and joining them by welding or engagement into one unit, since the entire blade is slanted in the rotational direction, the blade and the side plate are joined with pressing the blade in the direction of the rotational axis, which causes a stress to be exerted on the main plate side joined portion and prevents a force from being properly applied to the blade on the side plate side, leading to a difficulty in assembly.

[0006] JP 2008-2379 discloses a centrifugal fan including a circular main plate and a circular side plate and a plurality of hollow blades provided in parallel between the main plate and the side plate at predetermined blade intervals in the circumferential direction. An auxiliary air intake port for taking in air into a hollow part is provided on the side plate side of the blade, while an auxiliary air intake port is provided on the outer peripheral part negative pressure face side of the blade.

[0007] The present invention has been achieved to solve the above described problems. An object of the present invention is to provide a turbofan and an air conditioning apparatus provided with the same, which provides low-noise emission, ease to assemble, and good workability by suppressing a separation region at a blade

leading edge, a side plate side end, and a trailing edge, while minimizing performance degradation even if air flow resistance is added.

Means for Solving the Problems

[0008]

(1) According to the present invention, there is provided a turbofan as specified in the claims.

(2) An air conditioning apparatus according to the present invention includes the turbofan mounted, and a ventilating pressure loss unit provided on the side of an inlet opening of the turbofan.

Advantages

[0009]

- (i) With this arrangement, a turbofan according to the present invention provides a homogeneous wind speed distribution at the fan outlet opening. As a result, if a heat exchanger is provided downstream of the turbofan, air vertically uniformly flows in at least in the vicinity of the fan outlet opening, thereby suppressing an air flow that flows on the surface without passing through the heat exchanger due to a wind speed difference as well as reducing a pressure loss, resulting in a reduction in operating noise level.
- (ii) Also, an air conditioning apparatus according to the present invention suppresses air separation at a blade leading edge of the turbofan and provides low-noise operation, even if a ventilating pressure loss unit such as a filter is provided at a turbofan inlet opening.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a longitudinal sectional view showing an air conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a perspective view showing a turbofan according to Embodiment 2 of the present invention.

[Fig. 3] Fig. 3 is a plan view, partly in cross section, of a turbofan shown in Fig. 2, as viewed from a fan inlet opening side.

[Fig. 4] Fig. 4 is a side view showing a section taken along the line X-X of Fig. 3.

[Fig. 5] Fig. 5 is a side view showing a blade of a turbofan shown in Fig. 2.

[Fig. 6] Fig. 6 is a sectional view showing a section taken along the line L1-L1 of Fig. 5.

[Fig. 7] Fig. 7 is a sectional view showing a section taken along the line L2-L2 of Fig. 5.

[Fig. 8] Fig. 8 is a sectional view showing a section taken along the line L3-L3 of Fig. 5.

[Fig. 9] Fig. 9 is a sectional view showing a section taken along the line L4-L4 of Fig. 5.

[Fig. 10] Fig. 10 is a plan view showing a section taken along the line L5-L5 of Fig. 5.

[Fig. 11] Fig. 11 is a longitudinal sectional view showing a section taken along the line K1-K1 of Fig. 3.

[Fig. 12] Fig. 12 is a longitudinal sectional view showing a section taken along the line K2-K2 of Fig. 3.

[Fig. 13] Fig. 13 is a diagram showing relationship between a blade trailing edge inclination angle α and a noise level associated with the same air volume.

[Fig. 14] Fig. 14 is a diagram showing relationship between a circumferential curvature angle γ and a noise level associated with the same air volume.

[Fig. 15] Fig. 15 is a diagram showing relationship between an outlet angular difference $\Delta\beta_2$ and a noise level associated with the same air volume.

[Fig. 16] Fig. 16 is a diagram showing relationship between a curvature angle ε and a noise level associated with the same air volume.

[Fig. 17] Fig. 17 is a diagram showing relationship between an inlet angular difference $\Delta\beta_1$ and a noise level associated with the same air volume.

[Fig. 18] Fig. 18 is a perspective view showing a turbofan according to Embodiment 3 of the present invention.

[Fig. 19] Fig. 19 is a longitudinal sectional view of a blade of a turbofan shown in Fig. 18.

[Embodiment 1: air conditioning apparatus]

[0011] Fig. 1 is a longitudinal sectional view showing an air conditioning apparatus according to Embodiment 1 of the present invention. An air conditioning apparatus according to Embodiment 1 of the present invention is equipped with a turbofan according to Embodiment 2 to be described later, and is described below with reference to accompanying drawings.

[0012] In Fig. 1, a ceiling-embedded type air conditioning apparatus body (hereinafter referred to as "air conditioning apparatus body") 10 is mounted on a ceiling 21 of a room 20 in such a manner that it is embedded in a rectangular-shaped hole formed in the ceiling 21. In other words, the air conditioning apparatus body is a box having an opening formed at the bottom thereof and having a top plate 10a and a side plate 10b opposed to the top plate 10a. The side plate 10b has a side plate opening (communicating with a body inlet opening 10c) formed at the center thereof and has a bottom edge substantially flush with the ceiling 21, so an opening of the air conditioning apparatus body is also substantially flush with the ceiling 21.

[0013] In addition, decorative panel 11 shaped substantially in a rectangle in a plan view is installed on the side plate 10b or the ceiling 20 while facing the room 20 so as to cover the lower end of the side plate 10b and

the rectangular-shaped hole of the ceiling 21. The decorative panel 11 includes an inlet grill 11a, which is an inlet opening of air for the air conditioning apparatus body 10, provided at the center thereof, a filter 12 for removing dust from the air having passed through the inlet grill 11a, a panel outlet opening 11b formed along each side of the decorative panel 11. Each panel outlet opening 11b is provided with a wind direction vane 13.

[0014] Furthermore, inside the air conditioning apparatus body 10 a turbofan 1, a bell mouth 14 that forms an inlet air passage for the turbofan, a fan motor 15 for turning and driving the turbofan 1, and a heat exchanger 16 for performing heat exchange of room air drawn into the apparatus body (hereinafter referred to as "drawn air") are disposed respectively. The heat exchanger 16 is formed to have a substantial C-shaped form in the plan view, installed uprightly so as to surround the periphery of the turbofan 1, and connected to an outdoor unit (not illustrated) through connecting piping.

[0015] The air conditioning apparatus body 10 includes a body inlet opening 10c formed at the center thereof, and a body outlet opening 10d is formed around the body inlet opening 10c. The body inlet opening 10c communicates with the inlet grill 11a of the facing panel 11, while the body outlet opening 10d communicates with the panel outlet opening 11b of the decorative panel 11.

[0016] In the air conditioning apparatus 10 according to this arrangement, when the turbofan 1 rotates, the air in the room 20 is drawn into the turbofan 1 after passing through the inlet grill 11a of the decorative panel 11, the filter 12 removing dust, the body inlet opening 10c, and the bell mouth 14. Then, the air blows off into the heat exchanger 16 where the air is subjected to heat exchanging including heating or cooling and dehumidifying, and is blown out from the panel outlet opening 11b toward the room 20 through the body outlet opening 10d while subjected to wind direction control by the wind direction vane 13. Whereby, the air in the room 20 is air-conditioned (hereinafter referred to as "air conditioning").

[Embodiment 2: turbofan]

[0017] Figs. 2 through 17 are views showing a turbofan according to Embodiment 2 of the present invention. Fig. 2 is a perspective view. Fig. 3 is a plan view, partly in cross section, of a turbofan, as viewed from a fan inlet opening side. Fig. 4 a side view showing a section taken along the line X-X of Fig. 3. Fig. 5 is a partial side view. Figs. 6 through 9 are partial planar sectional views. Fig. 10 is a partial plan view. Figs. 11 and 12 are partial sectional views. Figs. 13 through 17 are diagrams showing the relationship between a noise level and an angle of each section.

[0018] Fig. 2 corresponds to a perspective view of Fig. 1, as seen when looking up at the ceiling 21. Fig. 4 and Fig. 1 (Embodiment 1) are upside-down views, where air is drawn from the upper side in Fig. 4 and blown off toward the right and left directions in Fig. 4. A top to bottom di-

rection in Fig. 4 is called "height direction", while a left to right direction and a face-to-back direction is called "horizontal direction" for convenience sake. In Fig. 1 and the other figures, the same reference numbers and symbols refer to the same components, and descriptions of the components are partially omitted.

[0019] Fig. 13 is a diagram showing relationship between a blade trailing edge inclination angle α and a noise level associated with the same air volume. Fig. 14 is a diagram showing relationship between a circumferential curvature angle γ and a noise level associated with the same air volume. Fig. 15 is a diagram showing relationship between an outlet angular difference $\Delta\beta_2$ and a noise level associated with the same air volume. Fig. 16 is a diagram showing relationship between a curvature angle ε at a blade leading edge end 4a3 and a noise level associated with the same air volume in relation to the ratio of an air flow resistance without dust accumulation on a filter disposed at an inlet side to that with dust accumulation. Fig. 17 is a diagram showing relationship between an inlet angular difference $\Delta\beta_1$ and a noise level associated with the same air volume, the inlet angular difference being an angular difference between an inlet angle the blade leading edge end and an inlet angle at a blade leading edge inner circumferential side end at a height of a concave-shaped bottom where a vertical camber line C12 becomes most along the opposite rotational direction in a blade outer circumferential surface.

[0020] In Figs. 2 through 5, the turbofan 1 is integrally formed of a main plate 2 of a body of revolution (disk) having a substantially angular-shaped section, a side plate 3 of a circular ring having a substantially circular arc section disposed so as to be opposed to the periphery of the main plate 2, and a plurality of blades 4 disposed so as to extended from the main plate 2 to the side plate 3. The main plate 2 includes a boss 2a formed at the center (convex portion having a substantially angular shaped section) thereof, the boss 2a being a fixing part to which a rotational shaft O of the fan motor 15 is secured. Accordingly, a rotational axis is parallel to the height direction and perpendicular to the horizontal direction.

[0021] In the side plate 3 in the form of a circular ring, a side plate opening formed at the center thereof forms a fan inlet opening 1a. The peripheral portion (skirt having a substantially angular shaped section) of the main plate 2 and the side plate 3 form wind guide walls, and a space defined by these components forms a fan outlet opening 1b. In other words, in Fig. 1, since the section of the peripheral edge of the main plate 2 and the section of the side plate 3 are rising toward the outer circumference, air flow is formed which rises (indicated by a downward arrow since the upside is down in Figs. 2 through 12) and then horizontally moves toward the outer circumference.

(Blade Layout)

[0022] In a plan view of the blade 4, the blade 4 is located farther away from the rotational axis O as it comes

nearer to the blade trailing edge from the blade leading edge 4a. The blade is connected at its end edge of the blade 4 close to the side plate 3 to the side plate in a region (4ec4~4g1) close to the blade trailing edge 4e, and is located at the side plate opening away from the side plate 3 in a region (4g1~4a3) close to the blade leading edge 4a. The blade 4 has a hollow structure having a cavity therein and an opening formed outside of the impeller of the main plate 2 in such a manner that a wall thickness T (equal to the distance between the blade outer circumferential surface and the blade inner circumferential surface) in a horizontal section perpendicular to the rotational axis O of the blade 4 decreases from a position close to the main plate 2 toward a position close to the side plate 3.

(Blade Trailing Edge)

[0023] The blade trailing edge 4e of the blade 4 is located on a hypothetical cylinder defined by connecting the circumferential edges of the main plate 2 and the side plate 3, and has a wavy form having at least two inflection points on such a hypothetical cylinder. Namely, an intersection of a horizontal camber line C1 and the blade trailing edge 4e depicts, in relation to an intersection 4ec1 as a main plate side joined point in the height direction, an intersection 4ec2 which is a main plate side inflection point having a curvature toward a rotational direction in a convex form at a predetermined position on the side of the main plate 2 closer to the center of the fan outlet opening 1b, an intersection 4ec3 which is a side plate side inflection point having a curvature toward the reverse rotational direction in a concave form on the side of the side plate 3 closer to the center of the fan outlet opening 1b, and an intersection 4ec4 which is a side plate side joined point of the side plate 3. In other words, a line G connecting between the main plate side joined portion 4ec1 and the side plate side joined portion 4ec4 is upright in the vicinity of the main plate 2 and the side plate 3 so as to be parallel to the rotational axis O, while the blade trailing edge on the side of the main plate 2 is inclined to the rotational direction A in relation to that on the side of the side plate 3 between the main plate side inflection point 4ec2 and the side plate side inflection point 4ec3 so that the blade trailing edge 4e has a substantial S shape.

[0024] At this time, the blade trailing edge 4e is located on a hypothetical cylinder defined by connecting the outer circumferential edges of the main plate 2 and the side plate 3, and a line G connecting a main plate side joined point 4ec1 and a side plate side joined point 4ec4 is orthogonal (orthogonal as a normal line) to the outer circumferential surface of the main plate 2 so as to be parallel to the rotational axis O.

[0025] Also, the blade trailing edge 4e is parallel to the normal line of the side plate 3 in the vicinity of the side plate 3. Furthermore, between main plate side curvature point 4ec2, which is a location in a main plate side curved

portion most projected to the rotational direction A, and the side plate side curvature point 4ec3, which is a location in a side plate side curved portion most projected to the opposite direction of the rotational direction A, the blade trailing edge 4e projects more to the rotational direction A as it is closer to the main plate 2, so as to be inclined in a side view. As a result, the blade trailing edge 4e has a substantial S shape.

[0026] Accordingly, on the blade outer circumferential surface 4b, drawn air is divided by the main plate side curvature point 4ec2 into the sides of the main plate 2 and the central part in the height direction of the outlet opening 1b, thereby preventing air flow from concentrating on the side of the main plate 2. An inclined section 4e5 between the main plate side curvature point 4ec2 and the side plate side curvature point 4ec3 exerts a force in the direction of the side plate 3, guiding the air flow. In addition, a portion between the side plate side curvature point 4ec3 and the side plate side joined point 4ec4 guides, on the blade inner circumferential surface 4c thereof, air flow coming from a portion around the side plate side joined portion 4g at the leading edge side plate side end 4a1 of the blade 4 to the side of the side plate 3 in the fan outlet opening 1b.

(Cross-sectional Shape of Blade)

[0027] The horizontal cross-sectional shape of the blade 4 will be described. Figs. 6 through 10 are sectional views taken along the line L1-L1, the line L2-L2, the line L3-L3, the line L4-L4, and the line L5-L5 of Fig. 4, respectively. The rotational direction is indicated by "Arrow A".

[0028] In other words, Fig. 6 is a sectional-view taken along the line L1-L1 at the main plate side end 4d joined to the main plate 2. Fig. 7 is a cross-sectional view taken along the line L2-L2 located on the side of the main plate 2 from the center of the fan outlet opening 1b. Fig. 8 is a cross-sectional view taken along the line L3-L3 located on the side of the side plate 3 from the center of the fan outlet opening 1b. Fig. 9 is a cross-sectional view taken along the line L4-L4 going through the side plate 3 in the fan outlet opening 1b. Fig. 10 is a cross-sectional view taken along the line L5-L5 when removing the side plate 3 corresponding to one blade 4.

[0029] In the L1-L1 section (Fig. 6), a wall thickness center line (equal to the center between the blade inner and outer circumferential surfaces) in the section is indicated by "horizontal camber line C1", and "the intersection of the horizontal camber line C1 and the blade leading edge 4a" and "the intersection of the horizontal camber line C1 and the blade trailing edge 4e" are indicated by "4ac1" and "4ec1", respectively.

[0030] Also, in the L2-L2 section (Fig. 7), a wall thickness center line in the section is indicated by "horizontal camber line C2", and "the intersection of the horizontal camber line C2 and the blade leading edge 4a" and "the intersection of the horizontal camber line C2 and the

blade trailing edge 4e" are indicated by "4ac2" and "4ec2", respectively.

[0031] Likewise, in the L3-L3 section (Fig. 8), "horizontal camber line C3" is indicated by "4ac3" and "4ec3". Also, in the L4-L4 section (Fig. 9), "horizontal camber line C3" is indicated by "4ac4" and "4ec4". Reference numerals "4ac1" and "4ec1" are added to each figure to make clear a phase in the height direction.

[0032] In Figs. 6 through 9, the blade 4 is an wing type blade which is gradually thickening toward the center of the blade from the blade inner circumference side leading edge 4a2, and is gradually thinning toward the blade trailing edge 4e.

[0033] In an L1-L1 section shown in Fig. 6, the blade 4 is slanted backward against the rotational direction A and radially outwardly curved. In a section L2-L2 shown in Fig. 7, the side of the main plate 2 of the blade trailing edge 4e is curved in a warped backward shape in the rotational direction A. In addition, in an L3-L3 section shown in Fig. 8, the blade trailing edge 4e is curved in a warped shape in the direction opposite to the rotational direction A against the main plate side joined part 4ec1.

[0034] IN the L4-L4 section shown in Fig. 9, the side plate side jointed point 4ec4 and the main plate side jointed point 4ec1 in the L1-L1 section shown in Fig. 6 have the same phase in a plan view as seen from the fan inlet opening 1a, and the leading edge inner circumference side end radially outwardly curves.

[0035] In addition, in a plan view shown in Fig. 10, the main plate side curvature point 4ec2 and the side plate side curvature point 4ec3 are disposed so as to make a predetermined angle γ across the main plate side jointed point 4ec1 and the side plate side jointed point 4ec4.

[0036] In Fig. 6 (L1-L1 section), the angle (acute angle) between a tangent line E1 to the horizontal camber line C1 at the intersection 4ec1 of the horizontal camber line C1 and the blade trailing edge 4e, and a tangent line F1 to a circle concentric with the rotational axis O and passing through the intersection 4ec1 is referred to as "outlet angle $\beta 21$ ".

[0037] In Fig. 7 (L2-L21 section), the angle (acute angle) between a tangent line E2 to the horizontal camber line C2 at the intersection 4ec2 of the horizontal camber line C2 and the blade trailing edge 4e, and a tangent line F2 to a circle concentric with the rotational axis O and passing through the intersection 4ec2 is referred to as "outlet angle $\beta 22$ ". Likewise, "outlet angle $\beta 23$ " and "outlet angle $\beta 24$ " are defined in Fig. 8 (L3-L3 section) and Fig. 9 (L4-L4 section), respectively.

[0038] The blade 4 is formed such that these outlet angles have the relationship of " $\beta 23 < \beta 21 = \beta 24 < \beta 22$ ".

(Blade Leading Edge)

[0039] In Figs. 2 and 3, the blade leading edge 4a on the blade 4 at the air inlet side has a shape defined by the side plate side end 4a1 and the inner circumferential side end 4a2 continuously formed with the leading-edge

end 4a3 as a bending point. The side plate side end 4a1 is tilted toward the fan inlet opening 1a as it approaches "side plate joined portion 4g (see Fig. 4) where the blade 4 and the side plate 3 are joined" from the leading-edge end 4a3. In other words, the side plate side end 4a1 approaches the side plate 3 being inclined so as to approach the normal line of the side plate 4.

[0040] In Fig. 3, the intersection of the horizontal camber line C1 and the blade leading edge inner circumferential side end 4a2 is called "intersection 4ac1", the intersection of the horizontal camber line C1 and the blade trailing edge end 4e is called "intersection 4ec1", and a line connecting the intersection 4ac1 and the intersection 4ec1 is called "chord line D".

[0041] A longitudinal section perpendicular to the chord line D in the vicinity of the blade leading edge inner circumferential end 4a2 is called "K1-K1 section", and the blade 4 in the K1-K1 section is shown in Fig. 11. A longitudinal section perpendicular to the chord line D at the end in a rotational direction 4g1 of the side plate joined portion (equal to the boundary between a joined region and a region located at the side plate opening) is called "K2-K2 section", and the blade 4 in the K2-K2 section is shown in Fig. 12.

[0042] In Figs. 11 and 12, vertical thickness center lines (equal to the center line between the blade inner circumferential surface and the blade outer circumferential surface) in the K1-K1 section and the K2-K2 section are called "vertical camber lines C12", while angles between the vertical camber line C12 and the rotational axis O at the blade leading edge end 4a3 (K1-K1 section) and at the blade side plate joined portion 4g1 (K2-K2 section) are called "curvature angle $\varepsilon 1$ " and curvature angle $\varepsilon 2$ ", respectively.

[0043] In Figs. 2, 11, and 12, a region apart from the side plate 3, in an end edge of the blade close to the side plate 3 (equal to the region located at the side plate opening), curves so as to be located more radially outward at a position closer to the blade leading edge 4a in a plan view, and expands so as to be farther away from the end edge at the curved region closer to the blade leading edge 4a in a side view.

[0044] In other words, the blade leading edge side plate side end 4a1 and the leading edge inner circumferential side end 4a2 on the side of the side plate 3 curves radially outward so that the curvature angle ε becomes larger at a position closer to the impeller inner circumference (equal to a position closer to the blade leading edge 4a) with the end in the rotational direction 4g1 on the blade outer circumferential surface of the side plate joined portion 4g being as a supporting point and the blade leading edge end 4a3 being as a power point.

[0045] Consequently, the curved region is formed to have a substantial triangle shape in a side view, causing an oblique "folding line B" to be created on the outer circumferential surface 4b of the blade 4 so as to extend toward the blade leading edge inner circumferential side end 4a2 of the blade leading edge from the end in the

rotational direction 4g1 to the main plate 2.

[0046] In addition, as shown in Figs. 4 and 11, the blade thickness T is made gradually larger so that the blade outer circumferential surface 4b of the blade leading edge 4a on the side of the main plate 2 curves radially outward, and at the same time the vertical camber line C12 curves radially outward.

[0047] In the K2-K2 section shown in Fig. 12, the blade outer circumferential surface 4b is substantially perpendicular to the outer circumferential surface of the main plate 2. Only the blade inner circumferential surface 4c on the side of the side plate 3 curves radially outward, and the blade 4 stands substantially upright with its thickness becoming smaller toward the side plate 3 from the main plate 2 (with increasing height), as a whole.

[0048] For inlet angles β_{11} , β_{12} , β_{13} , and β_{14} shown in cross-sectional views of Figs. 6 through 10, an inlet angle β_1 gradually becomes larger in a region from the blade leading edge end 4a3 to the side plate 3 to cause the inlet angle β_{14} at the blade leading edge end 4a3 to be the smallest, so that β_{14} is smaller than β_{11} , and β_{12} and β_{13} of middle portions in the height direction are greater than at least β_{11} and β_{14} , respectively ($\beta_{12} > \beta_{11}$, $\beta_{13} > \beta_{14}$).

[0049] As described above, in a side view as seen from the inner circumference, the blade leading edge 4a is at least so formed that the blade outer circumferential surface 4b on the sides of the blade side plate 4a1 and the main plate 2 is formed to have a convex shape in relation to the rotational direction A, while the blade inner circumferential surface 4c is formed so as to curve radially outward.

(Effects and Advantages)

[0050] As shown in Fig. 2, when being rotated by the fan motor 15 in the rotational direction A, the turbofan 1 having the above structure substantially radially blows out the room air (drawn air), which has been drawn through the fan inlet opening 1a and passed through the blade 4, through the fan outlet opening 1b, providing the following effects and advantages.

[0051]

(i) A homogeneous wind speed distribution is provided at the fan outlet opening 1b. As a result, if the heat exchanger 16 is provided downstream of the turbofan 1, the air flows uniformly into the heat exchanger, at least in the vicinity of the fan outlet opening 1b, thereby suppressing a secondary air flow that flows on the surface without passing through the heat exchanger 16 due to a wind speed difference as well as reducing a pressure loss, resulting in a reduction in operating noise level (see Fig. 1).

Also, the blade trailing edge 4e stands upright in the vicinity of the main plate 2 and the side plate 3, which allows a force parallel to the rotational axis O to be precisely applied at the time of welding work during

assembly, as compared with conventional turbofans where the trailing edge 4e is inclined in relation to the main plate 2 and the side plate 3, thereby preventing defective welding caused by the back clearance of the blade 4.

(ii) "Trailing edge inclination angle α_2 " or an inclination angle between an inclined section 4e5, which is located between the main plate side curvature point 4ec2 and the side plate side curvature point 4ec3, and a line G parallel to the rotational axis O is set at 10 to 30 degrees. This prevents a flow from concentrating on the blade outer circumferential surface 4b on the side of the side plate 3 in the fan outlet opening 1b. Also, this prevents a flow coming from the leading edge side plate side end 4a1 from concentrating on the blade inner circumferential surface 4c on the side of the side plate 3, thereby reducing a noise level as shown in the relationship between the trailing edge inclination angle α and the noise level associated with the same wind volume (see Fig. 13).

(iii) In Fig. 10, a circumferential curvature angle γ between a line connecting the impeller rotational axis with the main plate side curvature point 4ec2 and a line connecting the rotational axis with the side plate side curvature point 4ec3 is set at 5 to 15 degrees. When the heat exchanger 16 is disposed downstream of the fan outlet opening 1b, this arrangement allows the air flow to be dispersed even at the time when the blade trailing edge 4e becomes close to the heat exchanger 16 due to running turbofan 1 and an air flow resistance increases locally. Like the effects of the trailing edge inclination angle α , this arrangement also prevents a flow from concentrating on the side of the side plate 3 of the blade outer circumferential surface 4b in the fan outlet opening 1b, as well as prevents a flow coming from the leading edge side plate side 4a1 from concentrating on the side of the side plate 3 of the blade inner circumferential surface 4c, thereby reducing a noise level as shown in the relationship between the circumferential curvature angle γ and the noise level associated with the same wind volume (see Fig. 14).

(iv) In each cross sectional view of the blade in a plane perpendicular to the rotational axis, "angular difference $\Delta\beta_2$ " that is a difference between the outlet angle β_{22} at the main plate side curvature point 4ec2 and the outlet angle β_{23} at the side plate side curvature point 4ec3 is set at 20 to 35 degrees. Accordingly, in the air conditioning apparatus 10, the blade trailing edge is formed to have a substantial S shape with concave and convex curvature, so that even if a distance between the heat exchanger 16 (ventilating pressure-loss body having a substantial C shape in a plan view) disposed on the fan outlet side and the fan outlet opening 1b changes in the circumferential direction, the blade trailing edge 4e regulates an air flow due to the substantial S-shape.

Consequently, the present invention provides a

small change in wind speed distribution, thereby reducing a noise level, unlike conventional apparatuses in which an air flow concentrates on the fan outlet opening 1b on the side of the main plate 2, in a region where the fan 1 is close to the heat exchanger 16, which causes a greater separation on the side of the side plate 3 and a significant increase in noise level (see Fig. 15 showing the relationship between an outlet angular difference $\Delta\beta_2$ and a noise level associated with the same air volume).

(v) On the blade leading edge 4a, drawn air is smoothly introduced without hitting the outer circumferential surface 4b and producing a turbulent flow at the blade leading edge inner circumferential side end 4a2 on the side of the side plate 2 and at the side plate side induction portion 4b1 (leading edge side plate side end 4a1 curves radially outward) on the blade outer circumferential surface 4b, since, in a side view as seen from the center (rotational axis O), the outer circumferential surface 4b on the side of the side plate 3 and the main plate 2 curves to have a concave shape in relation to the rotational direction A.

This arrangement increases a blowing air volume at the same fan rotating speed, leading to a lower fan rotating speed than that for attaining the blowing air volume required for heat exchange of the air conditioning apparatus 10, which results in reduced operating noise levels as well as reduced motor power consumption due to performing a rotational drive of the fan with a reduced driving torque.

(vi) The blade outer circumferential surface 4b of the blade leading edge 4a on the side of the main plate 2 is formed to curve radially outward, which allows an air flow passing through the surface of the main plate 2 from the boss 2a to be directed toward the center of the blade height, preventing the air flow from concentrating on the side of the main plate 2, together with an air flow from the blade leading edge inner circumferential side end 4a2.

Also, the air flow can be smoothly introduced to the blade outer circumferential surface 4b without hitting the blade 4, thereby preventing turbulence.

Consequently, a homogeneous blown off wind speed distribution as well as reduced noise levels can be achieved by preventing a separation on the side plate side and a concentration on the main plate side, while conventional apparatuses suffer from the concentration of wind speed distribution on the main plate side in the fan outlet opening.

(vii) The blade inner circumferential surface 4c of the blade leading edge 4a on the side of the side plate 3 is formed to be slanted radially outward and curved, which allows drawn air on the inner circumferential surface 4c to smoothly flow along the slanted, curved surface toward the blade trailing edge 4e. This prevents the air flow separation occurring near the side plate 3 that is encountered in conventional turbofans,

thereby reducing noise levels.

(viii) With the end in the rotational direction 4g1 on the blade circumferential surface 4b at the side plate joined portion 4g being as a supporting point and the blade leading edge end 4a3 being as a power point, the "curvature angle ε (equal to an angle between the vertical camber line C12 and the a line parallel to the rotational axis O) becomes larger toward the inner circumference side of the impeller in a longitudinal cross section perpendicular to the chord D in a horizontal section at the blade main plate side end 4d. In other words, the leading edge side plate side end 4a1 and the leading edge inner circumferential side end 4a2 on the side of the side plate 3 curves radially outward toward the rotational direction surface 4b of the blade 4 (toward the blade leading edge inner circumferential side end 4a2 from the inner circumferential side end 4g1 of the side plate joined portion) so as to create a folding line B (oblique line, see Fig. 2) going toward the main plate 2 side.

This arrangement reduces the difference between an inflow at the blade leading edge inner circumferential side end 4a2 on the side of the side plate 3 and an inflow at the leading edge side plate side end 4a1, as compared with a conventional curvature with starting point on the horizontal line perpendicular to the rotational axis O.

(ix) The leading edge inner circumferential side end 4a2, and the leading edge side plate side end 4a1 are connectively formed into a substantially triangle shape with the leading edge end 4a3 as an apex, which homogenizes a vertical vortex occurring at the blade leading edge inner circumferential side end 4a2 and the leading edge side plate side end 4a1 around the blade leading edge end 4a3, causing to be stabilized by an air flow to be guided onto the blade inner circumferential surface 4c. Accordingly, even if the filter 12 (ventilating, pressure loss body disposed on the side of the fan inlet opening 1a) has dust built up thereon and air flow resistance is increased, air flow separation can hardly occurs, thereby suppressing noise levels deterioration to be low.

(x) Fig. 16 is a diagram showing the relationship between a curvature angle ε and "noise level in relation to air flow resistance ratio" associated with the same air volume. Namely, it shows "noise level in relation to air flow resistance ratio" that is the ratio of a value for the filter having no dust buildup to that for the filter having a dust buildup. As shown in Fig. 16, if ε falls within a range between 25 and 45 degrees, a low-noise turbofan and a low-noise air conditioning apparatus which hardly suffers from air flow separation regardless of a change in air flow resistance at the fan inlet opening 1a can be obtained.

(xi) In addition, as shown in Fig. 12, the blade 4 has its thickness T decreasing toward the side plate 3 in the height direction of the fan from the main plate 2 and has a hollow structure having an opening 2b on

the outside of the impeller of the main plate 2, which contributes to a reduction in weight. This arrangement reduces starting torque exerted on the boss 2a at a start of a fan motor as well as suppresses distortion, leading to an improvement in durability of the turbofan 1.

(xii) Furthermore, in the blade 4, the longitudinal cross section K1-K1 shown in Fig. 6 (longitudinal cross section containing the end in the rotational direction 4g1 in the side plate joined portion of the blade 4 perpendicular to the chord D in a horizontal cross section at the blade main plate side end 4d) and a predetermined region toward the downstream blade trailing edge 4e are formed so as to substantially stand upright in parallel to the rotational axis O in relation to the main plate 2. Consequently, when the main plate 2 is pressed against the blade 4 in parallel to the rotational axis O in order to weld the blade 4 and the side plate 2 into one body, "stress concentration at the blade main plate side end 4d" to be encountered by a conventional blade being slanted relative to the main plate 2 can be mitigated, thereby preventing the buckling of the blade 4 so as to lead to the facilitation of assembly as well as improved reliability.

(xiii) As to an inlet angle β_1 in each cross-sectional view of the blade 4 taken along a plane perpendicular to the rotational axis O, the inlet angle β_{14} at the blade leading edge end 4a3 is the smallest in the leading edge 4a. In addition, the inlet angle β_1 at a portion close to the center in the impeller height direction in the blade leading edge inner circumferential end 4a2, is formed radially inward so as to be greater than the inlet angle β_{11} on the main plate side and the inlet angle β_{14} at the blade leading end, that is, it has a relationship of $\beta_1 > \beta_{11} > \beta_{14}$.

In addition, the inlet angle β_1 is designed to gradually become larger toward the side plate joined portion 4g from the blade leading edge end 4a3 in the blade side plate side end 4a1, thereby reducing "an incident angle δ " which is the angular difference between "inlet flow J" and the inlet angle β_1 on a horizontal section perpendicular to the rotational axis O at the blade leading edge inner circumferential side end 4a2, as well as allowing drawn air to be smoothly drawn in with less separation, which leads to a reduction in noise levels.

(xiv) From the blade leading edge end 4a3 to the side plate joined portion 4g in the blade leading edge side plate side end 4a1, the drawn air is radially introduced with a slope toward the fan inlet opening 1a, and further radially introduced by gradually increasing the inlet angle β , so as to mitigate the separation on the side of the side plate 3 as well as to homogenize the wind speed distribution in the fan outlet opening 1b.

(xv) An angular difference between the inlet angle β_{14} (see Figs. 8 and 11) at the blade leading edge

end 4a3 and the inlet angle β_{12} at the leading edge inner circumferential side end 4a2 (see Figs. 7 and 11) at a height position on a concave-shaped bottom in which the vertical camber line C12 is most directed in the opposite rotational direction on the blade outer circumferential surface 4b is set as "angular difference $\Delta\beta_1$ ".

With this arrangement, as shown in Fig. 17, although excessively greater angular difference $\Delta\beta_1$ causes a separation on the blade inner circumferential surface 4c on the side of the main plate 2 as well as increased noise levels, the angular difference $\Delta\beta_1$ of 10 to 20 degrees causes a reduction in noise levels.

(xvi) Incidentally, a blade trailing edge 4e formed into a curved shape as substantial S shape and a blade leading edge 4a formed to curve radially outward provide noise reduction effects individually, as compared with the conventional blade.

[0052] In addition, the combination of these shapes allows the drawn air to be smoothly drawn in along the entire blade leading edge 4a, causing a rectified air flow to be drawn in toward the blade trailing edge 4e. This facilitates the flow of the drawn air along the substantial S shaped surface of the blade with less turbulence, further homogenizing the wind speed distribution and reducing noise levels by synergistic effect.

[0053] As described above, a turbofan according to the present invention is a low-noise, reliable, and durable turbofan. An air conditioning apparatus provided with such a turbofan ensures a comfortable usage environment free from harsh noise as well as a trouble free use for a long time. Thus, a low-cost, high-quality air conditioning apparatus can be provided.

[Embodiment 3: turbofan]

[0054] Figs. 18 and 19 show a turbofan according to Embodiment 3 of the present invention. Fig. 18 is a perspective view, while Fig. 19 is a partial cross-sectional view (to be precise, a longitudinal sectional view of the blade 4 in a plane perpendicular to the chord D at the blade main plate side end 4b). The same symbols and reference numerals in Figs. 18 and 19 as those in Embodiment 2 (Figs. 2 through 12) refer to the same components, and repeated descriptions of the same components are partially omitted.

[0055] In Fig. 18, a leading edge side plate side end 4a1 which is an edge of the blade 4 close to the side plate 3 curved so as to be placed more radially outward as it becomes closer to the leading edge inner circumferential side end 4a2 in a plan view, in a region away from the side plate 3 (equal to a region located at the side plate opening), and the curved region expands so as to become away from that end as it becomes closer to the leading edge inner circumferential side end 4a2 in a side view.

[0056] In other words, the turbofan 30 has a folding line B heading gradually in the direction of the main plate 2, which is formed in the radially outward curving leading edge side plate side end 4a1 of the blade 4 and in the blade outer circumferential surface 4b at the leading edge inner circumferential side end 4a2 on the side of the side plate 3 so as to be directed toward the leading edge inner circumferential side end 4a2 of the blade 4 from the end in the rotational direction 4g1 in the blade outer circumferential surface 4b at the side plate joined portion 4g.

[0057] In addition, a rectangular-shaped concave groove 5 is formed in the blade inner circumferential surface 4c in the curved region so as to be substantially perpendicular to the folding line B and obliquely outwardly extend to the side of the main plate 2 from the side of the side plate 3 in relation to the rotational axis O.

[0058] In Fig. 19, the concave groove 5 becomes shallower as it is closer to the leading edge side plate side end 4a1.

[0059] In other words, the blade 4 is formed of a component constituting the blade outer circumferential surface and a component constituting the blade inner circumferential surface, and has a dual structure having a hollow formed therein. These two components are joined together at the leading edge side plate side end 4a1, and the distance between them becomes larger at a position further away from the leading edge side plate side end 4a1.

[0060] The groove bottom 5a of the concave groove 5 is formed with the component constituting the blade outer circumferential surface, so the depth of the concave groove 5 corresponds to the distance between the inner circumferential surface of the component constituting the blade outer circumferential surface and the inner circumferential surface of the component constituting the blade inner circumferential surface.

[0061] When driven by a fan motor in the rotational direction A, the turbofan 30 having the above structure draws air through the fan inlet opening 1a and substantially radially blows out the drawn air in the rotational direction through the fan outlet opening 1b, after passing through the blade 4.

[0062] When air is drawn into the blade 4, the air smoothly flows on and along the blade outer circumferential surface 4c to the blade trailing edge without any turbulence, since the leading edge side plate side end 4a1 curves in the radially outward direction. Also, the concave groove 5 extends obliquely so as to expand toward the side of the main plate 2 from the side of the side plate 3 in relation to the rotational axis O, thereby allowing the groove bottom 5a to rectify the air flow and suppress the turbulence, leading to further reduction in noise levels.

[0063] The groove bottom 5a of the concave groove 5 is formed to extend along the blade outer circumferential surface 4b, so as to make the thickness of the blade 4 smaller. In the case of a turbofan formed of a thermoplastic resin, this arrangement prevents a surface sink

due to smaller wall thickness even at a curved portion which tends to have a larger wall thickness, resulting in improved reliability in forming.

[0064] In particular, the turbofan 30, if installed on an air conditioning apparatus 10 (see Fig. 1) having a ventilating pressure loss body such as a filter disposed at the fan inlet opening 1a thereof, prevents an air flow separation and maintains low noise levels even if dust gradually accumulates on the filter and results in increased air flow resistance.

Industrial Applicability

[0065] A turbofan according to the present invention can be widely used for household use and industrial use due to its low-noise and high manufacturing reliability. In addition, such a turbofan can be widely used in home-use and industrial air conditioning apparatuses.

Claims

1. A turbofan comprising:

a disc-shaped main plate (2) having a boss (2a) that is a fixed portion to which a rotational shaft (O) of a motor is secured;

an annular side plate (3) having a side plate opening formed at the center thereof and forming a wind guide wall together with the main plate (2); and

a plurality of blades (4) mounted so as to extend between the main plate (2) and the side plate (3); in a plan view of the blade (4), each blade (4) being positioned farther away from the rotational shaft (O), when coming from a blade leading edge (4a) to a blade trailing edge (4e); wherein an outer circumferential surface (4b) and an inner circumferential surface (4c) of the blade (4) at the blade leading edge (4a) have a central region in the height direction substantially parallel to the rotational shaft (O), **characterized in that** the blade has a skirt area close to the main plate (2) that is located more radially outward of the main plate (2) when coming closer to the main plate (2) at the blade leading edge (4a), and another skirt area close to the side plate (3) that is located more radially outward of the side plate (3) when coming closer to the side plate (3) at the blade leading edge (4a), and the blade outer circumferential surface (4b) of the blade leading edge (4a) on the side of the main plate (2) curves outward of the main plate (2).

2. The turbofan of claim 1, wherein, the blade (4) is connected at its end edge close to the side plate (3) to the side plate (3) in a region close to the blade

trailing edge (4e), and is located at the side plate opening away from the side plate (3), in a region close to the blade leading edge (4a), and the blade trailing edge (4e) of the blade (4) has a wavy form having at least two inflection points located on a hypothetical cylinder connecting outer circumferential edges of the main plate (2) and the side plate (3) and has a main plate side curved portion projecting to a rotational direction in a region closer to the main plate (2) and a side plate side curved portion projecting in an opposite rotational direction in a region closer to the side plate (3).

3. The turbofan of claim 1, wherein, in a region located at the side plate opening, an end edge of the blade (4) close to the side plate (3) curves so as to be located more radially outward as the end edge comes closer to the blade leading edge (4a) in a plan view, and expands so as to be positioned farther away from the end edge as its curved region comes closer to the blade leading edge (4a) in a side view.
4. The turbofan of any one of claims 1 to 3, wherein a line connecting a portion where the blade trailing edge (4e) is joined to the main plate (2) and a portion where the blade trailing edge (4e) is joined to the side plate (3) is parallel to the rotational shaft (O).
5. The turbofan of any one of claims 1 to 4, wherein the blade (4) has a taper-shaped, hollow structure having a hollow formed therein where the distance between the blade outer circumferential surface (4b) and the blade inner circumferential surface (4c) is gradually smaller toward the side plate (3) from the main plate (2).
6. The turbofan of any one of claims 1 to 5, wherein a center line between the blade outer circumferential surface (4b) and the blade inner circumferential surface (4c) is parallel to the rotational shaft (O) in a region where the blade (4) is joined to the side plate (3).
7. The turbofan of claim 2 or 4, wherein, in a side view of an end of the blade trailing edge (4e), an inclined line connecting a maximum projection (4ec2) in the rotational direction in the main plate side curved portion and a maximum projection (4ec3) in the opposite direction in the side plate curved portion is inclined at 10 to 30 degrees to a vertical line connecting a connecting portion with the main plate (2) and a connecting portion with the side plate (3).
8. The turbofan of claim 2 or 4, wherein, a circumferential curvature angle (γ), which is an angle in a plan view, made by a line connecting a center of the rotational shaft (O) and an intersection of a horizontal camber line showing a center line between the blade

outer circumferential surface (4b) and the blade inner circumferential surface (4c) and an outer circumferential edge of the main plate (2) in a plan view of the connecting portion with the main plate (2), and a line connecting the center of the rotational shaft (O) and the intersection of the horizontal camber line showing the center line between the blade outer circumferential surface (4b) and the blade inner circumferential surface (4c) and a circumferential edge of the side plate (3) in a plan view of the connecting portion with the side plate (3) is 5 to 15 degrees.

9. The turbofan of claim 2 or 4, wherein an angular difference ($\Delta\beta 2$) between a main plate side outlet angle, in a plan view of the main plate side curved portion, formed between a tangent to a horizontal camber line showing a center line between the blade outer circumferential surface (4b) and the blade inner circumferential surface (4c) at an end of the blade trailing edge (4e) and a tangent at the end of the blade trailing edge (4e) to a circle passing through the end of the blade trailing edge (4e) having its center at the center of the rotational shaft (O), and a side plate side outlet angle, in a plan view of the side plate side curved portion, between a tangent to the horizontal camber line showing the center line between the blade outer circumferential surface (4b) and the blade inner circumferential surface (4c) at the end of the blade trailing edge (4e) and a tangent at the end of the blade trailing edge (4e) to the circle passing through the end of the blade trailing edge (4e) having its center at the center of the rotational shaft (O), is 20 to 35 degrees.
10. The turbofan of claim 3, wherein, in a side view, a curvature angle (ε) which is an angle formed between a tangent at an end of the blade leading edge (4a) to the vertical camber line showing the center line between the blade outer circumferential surface (4b) and the blade inner circumferential surface (4c) and the rotational shaft (O) is 25 to 45 degrees.
11. The turbofan of any one of claims 1 to 10, wherein, at an end of the blade leading edge (4a) in a plan view, a blade side plate side inlet angle that is an inlet angle at a position closer to the side plate (3), a blade middle inlet angle that is an inlet angle in the middle of the side plate (3) and the main plate (2) in a height direction, and a blade main plate side inlet angle that is an inlet angle at a position closer to the main plate (2) have a relationship of "the blade middle inlet angle > the blade main plate side inlet angle > the blade side plate side inlet angle".
12. The turbofan of claim 11, wherein at the end of the blade leading edge (4a) in a plan view, an angular difference ($\Delta\beta 1$) between a blade middle inner circumferential inlet angle that is an inlet angle at an

inner circumferential side end in the middle of the side plate (3) and the main plate (2) in a height direction and a blade side plate side inlet angle that is an inlet angle at an end closer to the side plate (3) is 10 to 20 degrees.

13. The turbofan of claim 3, wherein a concave groove (5) is formed on the blade inner circumferential surface in the curved region of the blade (4) so as to extend to an end close to the side plate (3), a folding line (B) is defined at a boundary of the curved region and the blade inner circumferential surface except the curved region, and the concave groove (5) is substantially parallel to the folding line (B); wherein, optionally, the concave groove (5) has a rectangular section and is gradually shallowing toward an end close to the side plate (3).

14. An air conditioning apparatus, wherein the turbofan of any one of claims 1 to 13 is mounted, and a ventilating pressure loss unit (12) is provided at an air inlet opening of the turbofan.

15. An air conditioning apparatus, wherein the turbofan of any one of claims 1 to 13 is mounted, and a ventilating pressure loss unit (12) is provided at an air outlet opening of the turbofan.

Patentansprüche

1. Turboventilator, umfassend:

eine scheibenförmige Hauptplatte (2) mit einem Vorsprung (2a), der ein fester Abschnitt ist, an dem eine Drehachse (O) eines Motors befestigt ist;

eine kreisförmige Seitenplatte (3) mit einer an ihrer Mitte gebildeten Seitenplattenöffnung, die zusammen mit der Hauptplatte (2) eine Windleitwand bildet; und

eine Vielzahl von Flügeln (4), die so angebracht sind, dass sie sich zwischen der Hauptplatte (2) und der Seitenplatte (3) erstrecken;

wobei in einer Draufsicht des Flügels (4) jeder Flügel (4) weiter von der Drehachse (O) weg positioniert ist, wenn man von einer Flügelvorderkante (4a) zu einer Flügelhinterkante (4e) kommt;

wobei

eine Außenumfangsfläche (4b) und eine Innenumfangsfläche (4c) des Flügels (4) an der Flügelvorderkante (4a) einen zentralen Bereich in der Höhenrichtung im Wesentlichen parallel zu der Drehachse (O) aufweisen,

dadurch gekennzeichnet, dass

der Flügel ein Randgebiet in der Nähe der Hauptplatte (2) aufweist, das sich weiter radial

nach außen von der Hauptplatte (2) befindet, wenn man sich der Hauptplatte (2) an der Flügelvorderkante (4a) nähert, und ein anderes Randgebiet in der Nähe der Seitenplatte (3), das sich weiter radial nach außen von der Seitenplatte (3) befindet, wenn man sich der Seitenplatte (3) an der Flügelvorderkante (4a) nähert, und

sich die Außenumfangsfläche (4b) der Flügelvorderkante (4a) auf der Seite der Hauptplatte (2) von der Hauptplatte (2) nach außen krümmt.

2. Turboventilator nach Anspruch 1, wobei der Flügel (4) an seiner Endkante in der Nähe der Seitenplatte (3) mit der Seitenplatte (3) in einem Bereich in der Nähe der Flügelhinterkante (4e) verbunden ist und sich an der Seitenplattenöffnung von der Seitenplatte (3) weg befindet, in einem Bereich in der Nähe der Flügelvorderkante (4a), und wobei die Flügelhinterkante (4e) des Flügels (4) eine wellenförmige Form mit mindestens zwei Wendepunkten aufweist, die sich auf einem hypothetischen Zylinder befinden, der Außenumfangskanten der Hauptplatte (2) und der Seitenplatte (3) verbindet, und einen gekrümmten Hauptplattenseitenabschnitt aufweist, der in eine Drehrichtung in einem Bereich näher an der Hauptplatte (2) vorsteht, und einen gekrümmten Seitenplattenseitenabschnitt aufweist, der in eine entgegengesetzte Drehrichtung in einem näheren Bereich an der Seitenplatte (3) vorsteht.

3. Turboventilator nach Anspruch 1, wobei sich in einem Bereich, der sich an der Seitenplattenöffnung befindet, eine Endkante des Flügel (4) in der Nähe der Seitenplatte (3) krümmt, um weiter radial nach außen platziert zu sein, wenn sich die Endkante in einer Draufsicht der Flügelvorderkante (4a) nähert, und sich erweitert, um weiter von der Endkante weg positioniert zu sein, wenn sich der gekrümmte Bereich in einer Seitenansicht der Flügelvorderkante (4a) nähert.

4. Turboventilator nach einem der Ansprüche 1 bis 3, wobei eine Linie, die einen Abschnitt, wo die Flügelhinterkante (4e) mit der Hauptplatte (2) verbunden ist, mit einem Abschnitt verbindet, wo die Flügelhinterkante (4e) mit der Seitenplatte (3) verbunden ist, parallel zu der Drehachse (O) ist.

5. Turboventilator nach einem der Ansprüche 1 bis 4, wobei der Flügel (4) eine verjüngt geformte hohle Struktur mit einem darin gebildeten Hohlraum aufweist, wo sich der Abstand zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) stufenweise in Richtung der Seitenplatte (3) von der Hauptplatte (2) verkleinert.

6. Turboventilator nach einem der Ansprüche 1 bis 5,

wobei eine Mittellinie zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) parallel zu der Drehachse (O) in einem Bereich ist, wo der Flügel (4) mit der Seitenplatte (3) verbunden ist.

7. Turboventilator nach Anspruch 2 oder 4, wobei in einer Seitenansicht eines Endes der Flügelhinterkante (4e) eine schräge Linie, die einen maximalen Vorsprung (4ec2) in der Drehrichtung in dem gekrümmten Hauptplattenseitenabschnitt mit einem maximalen Vorsprung (4ec3) in der entgegengesetzten Richtung in dem gekrümmten Seitenplattenabschnitt verbindet, 10 bis 30 Grad zu einer vertikalen Linie hin geneigt ist, die einen Verbindungsabschnitt mit der Hauptplatte (2) und einen Verbindungsabschnitt mit der Seitenplatte (3) verbindet.
8. Turboventilator nach Anspruch 2 oder 4, wobei ein Umfangskrümmungswinkel (γ), der ein Winkel in einer Draufsicht ist, gebildet von einer Linie, die ein Zentrum der Drehachse (O) mit einem Schnittpunkt einer horizontalen Krümmungslinie verbindet, die eine Mittellinie zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) und einer Außenumfangskante der Hauptplatte (2) in einer Draufsicht des Verbindungsabschnitts mit der Hauptplatte (2) zeigt, und einer Linie, die das Zentrum der Drehachse (O) mit dem Schnittpunkt der horizontalen Krümmungslinie verbindet, die die Mittellinie zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) und einer Umfangskante der Seitenplatte (3) in einer Draufsicht des Verbindungsabschnitts mit der Seitenplatte (3) zeigt, 5 bis 15 Grad ist.
9. Turboventilator nach Anspruch 2 oder 4, wobei eine Winkeldifferenz ($\Delta\beta_2$) zwischen einem Hauptplattenseitenaustrittswinkel in einer Draufsicht des gekrümmten Hauptplattenseitenabschnitts, gebildet zwischen einer Tangente zu einer horizontalen Krümmungslinie, die eine Mittellinie zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) an einem Ende der Flügelhinterkante (4e) zeigt, und einer Tangente an dem Ende der Flügelhinterkante (4e) zu einem Kreis, der durch das Ende der Flügelhinterkante (4e) mit dem Zentrum an dem Zentrum der Drehachse (O) verläuft, und einem Seitenplattenseitenaustrittswinkel in einer Draufsicht des gekrümmten Seitenplattenabschnitts zwischen einer Tangente zu der horizontalen Krümmungslinie, die die Mittellinie zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) an dem Ende der Flügelhinterkante (4e) zeigt, und einer Tangente an dem Ende der Flügelhinterkante (4e) zu dem Kreis, der durch das Ende der Flügelhinterkante (4e) mit dem Zentrum an dem Zentrum der Drehachse (O)

verläuft, 20 bis 35 Grad ist.

10. Turboventilator nach Anspruch 3, wobei in einer Seitenansicht ein Krümmungswinkel (ε), der ein Winkel ist, der zwischen einer Tangente an einem Ende der Flügelvorderkante (4a) zu der vertikalen Krümmungslinie, die die Mittellinie zwischen der Flügelaußenumfangsfläche (4b) und der Flügelinnenumfangsfläche (4c) zeigt, und der Drehachse (O) 25 bis 45 Grad ist.
11. Turboventilator nach einem der Ansprüche 1 bis 10, wobei an einem Ende der Flügelvorderkante (4a) in einer Draufsicht ein Flügelseitenplattenseiteneintrittswinkel, das heißt ein Eintrittswinkel an einer Position näher an der Seitenplatte (3), ein Flügelmitteintrittswinkel, das heißt ein Eintrittswinkel in der Mitte der Seitenplatte (3) und der Hauptplatte (2) in einer Höhenrichtung, und ein Flügelhauptplattenseiteneintrittswinkel, das heißt ein Eintrittswinkel an einer Position näher an der Hauptplatte (2), die folgende Beziehung haben: "Flügelmitteintrittswinkel > Flügelhauptplattenseiteneintrittswinkel > Flügelseitenplattenseiteneintrittswinkel".
12. Turboventilator nach Anspruch 11, wobei an dem Ende der Flügelvorderkante (4a) in einer Draufsicht eine Winkeldifferenz ($\Delta\beta_1$) zwischen einem Flügelmitteintrittswinkel, das heißt ein Eintrittswinkel an einem Innenumfangsseitenende in der Mitte der Seitenplatte (3) und der Hauptplatte (2) in einer Höhenrichtung, und einem Flügelseitenplattenseiteneintrittswinkel, das heißt ein Eintrittswinkel an einem Ende näher an der Seitenplatte (3), 10 bis 20 Grad ist.
13. Turboventilator nach Anspruch 3, wobei eine konkave Nut (5) auf der Flügelinnenumfangsfläche in dem gekrümmten Bereich des Flügels (4) gebildet ist, um sich bis zu einem Ende in der Nähe der Seitenplatte (3) zu erstrecken, wobei eine Faltlinie (B) an einem Randbereich des gekrümmten Bereichs und der Flügelinnenumfangsfläche mit Ausnahme des gekrümmten Bereichs definiert ist, und die konkave Nut (5) im Wesentlichen parallel zu der Faltlinie (B) ist; wobei optional die konkave Nut (5) einen rechteckigen Bereich aufweist und stufenweise in Richtung eines Endes in der Nähe der Seitenplatte (3) schmaler wird.
14. Klimaanlagevorrichtung, wobei der Turboventilator nach einem der Ansprüche 1 bis 13 befestigt ist und eine Ventilationsdruckabfalleinheit (12) an einer Lufteintrittsöffnung des Turboventilators bereitgestellt ist.
15. Klimaanlagevorrichtung, wobei der Turboventilator nach einem der Ansprüche 1 bis 13 befestigt ist und

eine Ventilationsdruckabfalleinheit (12) an einer Luftaustrittsöffnung des Turboventilators bereitgestellt ist.

Revendications

1. Turbosoufflante comprenant :

une plaque principale en forme de disque (2) présentant un moyeu (2a) qui est une partie fixe à laquelle l'arbre de rotation (O) d'un moteur est fixé ;

une plaque latérale annulaire (3) présentant une ouverture de plaque latérale formée au centre de celle-ci et formant une paroi de guidage de vent conjointement avec la plaque principale (2) ; et

une pluralité de pales (4) montées de manière à s'étendre entre la plaque principale (2) et la plaque latérale (3) ;

dans une vue en plan de la pale (4), chaque pale (4) étant positionnée plus loin de l'arbre de rotation (O), en allant d'un bord d'attaque de pale (4a) à un bord de fuite de pale (4e) ;

dans laquelle

une surface circonférentielle externe (4b) et une surface circonférentielle interne (4c) de la pale (4) au niveau du bord d'attaque de pale (4a) présentent une région centrale dans le sens de la hauteur sensiblement parallèle à l'arbre de rotation (O),

caractérisée en ce que

la pale présente une zone de socle proche de la plaque principale (2) qui est située plus radialement à l'extérieur de la plaque principale (2) en se rapprochant de la plaque principale (2) au niveau du bord d'attaque de pale (4a), et une autre zone de socle près de la plaque latérale (3) qui est située plus radialement à l'extérieur de la plaque latérale (3) en se rapprochant de la plaque latérale (3) au niveau du bord d'attaque de pale (4a), et

la surface circonférentielle externe de pale (4b) du bord d'attaque de pale (4a) sur le côté de la plaque principale (2) s'incurve vers l'extérieur de la plaque principale (2).

2. Turbosoufflante selon la revendication 1, dans laquelle la pale (4) est reliée sur son bord d'extrémité près de la plaque latérale (3) sur la plaque latérale (3) dans une région proche du bord de fuite de pale (4e) et est située sur l'ouverture de la plaque latérale à distance de la plaque latérale (3), dans une région proche du bord d'attaque de pale (4a), et le bord de fuite de pale (4e) de la pale (4) présente une forme ondulée présentant au moins deux points d'inflexion situés sur un cylindre théorique reliant des bords cir-

conférentiels externes de la plaque principale (2) et de la plaque latérale (3) et présente une partie incurvée côté plaque principale faisant saillie vers une direction de rotation dans une région plus proche de la plaque principale (2) et une partie incurvée côté plaque latérale faisant saillie dans une direction de rotation opposée dans une région plus proche de la plaque latérale (3).

3. Turbosoufflante selon la revendication 1, dans laquelle, dans une région située sur l'ouverture de la plaque latérale, un bord d'extrémité de la pale (4) proche de la plaque latérale (3) s'incurve de manière à être située plus radialement vers l'extérieur tandis que le bord d'extrémité se rapproche du bord d'attaque de pale (4a) dans une vue plane, et s'étend de manière à être positionnée plus loin du bord d'extrémité tandis que sa région incurvée se rapproche du bord d'attaque de pale (4a) dans une vue latérale.

4. Turbosoufflante selon l'une quelconque des revendications 1 à 3, dans laquelle une ligne reliant une partie où le bord de fuite de pale (4e) est relié à la plaque principale (2) et une partie où le bord de fuite de pale (4e) est relié à la plaque latérale (3) est parallèle à l'arbre de rotation (O).

5. Turbosoufflante selon l'une quelconque des revendications 1 à 4, dans laquelle la pale (4) présente une structure creuse de forme conique présentant un creux formé à l'intérieur de celle-ci où la distance entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) est progressivement inférieure vers la plaque latérale (3) depuis la plaque principale (2).

6. Turbosoufflante selon l'une quelconque des revendications 1 à 5, dans laquelle une ligne centrale entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) est parallèle à l'arbre de rotation (O) dans une région où la pale (4) est reliée à la plaque latérale (3).

7. Turbosoufflante selon la revendication 2 ou 4, dans laquelle, dans une vue latérale d'une extrémité du bord de fuite de pale (4e), une ligne inclinée reliant une saillie maximale (4ec2) dans la direction de rotation dans la partie incurvée côté plaque principale et une saillie maximale (4ec3) dans la direction opposée dans la partie incurvée de plaque latérale est inclinée de 10 à 30 degrés vers une ligne verticale reliant une partie de raccordement avec la plaque principale (2) et une partie de raccordement avec la plaque latérale (3).

8. Turbosoufflante selon la revendication 2 ou 4, dans laquelle un angle de courbure circonférentiel (γ), qui est un angle dans une vue en plan, créé par une

- ligne reliant un centre de l'arbre de rotation (O) et une intersection d'une ligne de cambrure horizontale indiquant une ligne centrale entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) et un bord circonférentiel externe de la plaque principale (2) dans une vue en plan de la partie de raccordement avec la plaque principale (2), et une ligne reliant le centre de l'arbre de rotation (O) et l'intersection de la ligne de cambrure horizontale indiquant la ligne centrale entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) et un bord circonférentiel de la plaque latérale (3) dans une vue plane de la partie de raccordement avec la plaque latérale (3) est de 5 à 15 degrés.
- 5
- 10
- 15
9. Turbosoufflante selon la revendication 2 ou 4, dans laquelle une différence d'angle ($\Delta\beta 2$) entre un angle de sortie côté plaque principale, dans une vue en plan de la partie incurvée côté plaque principale, formé entre une tangente à une ligne de cambrure horizontale indiquant une ligne centrale entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) à une extrémité du bord de fuite de pale (4e) et une tangente à l'extrémité du bord de fuite de pale (4e) vers un cercle passant par l'extrémité du bord de fuite de pale (4e) et présentant son centre au centre de l'arbre de rotation (O), et un angle de sortie côté plaque latérale, dans une vue en plan de la partie incurvée côté plaque latérale, entre une tangente vers la ligne de cambrure horizontale indiquant la ligne centrale entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) à l'extrémité du bord de fuite de pale (4e) et une tangente à l'extrémité du bord de fuite de pale (4e) vers le cercle passant par l'extrémité du bord de fuite de pale (4e) présentant son centre au centre de l'arbre de rotation (O), est de 20 à 35 degrés.
- 20
- 25
- 30
- 35
10. Turbosoufflante selon la revendication 3, dans laquelle, dans une vue latérale, un angle de courbure (ϵ) qui est un angle formé entre une tangente à une extrémité du bord d'attaque de pale (4a) vers la ligne de cambrure verticale indiquant la ligne centrale entre la surface circonférentielle externe de pale (4b) et la surface circonférentielle interne de pale (4c) et l'arbre de rotation (O) est de 25 à 45 degrés.
- 40
- 45
11. Turbosoufflante selon l'une quelconque des revendications 1 à 10, dans laquelle, à une extrémité du bord d'attaque de pale (4a) dans une vue en plan, un angle d'entrée côté plaque latérale de pale qui est un angle d'entrée à une position plus proche de la plaque latérale (3), une angle d'entrée médian de pale qui est un angle d'entrée au milieu de la plaque latérale (3) et de la plaque principale (2) dans le sens de la hauteur, et un angle d'entrée côté plaque prin-
- 50
- 55
- cipale de pale qui est un angle d'entrée à une position plus proche de la plaque principale (2) présentent un rapport de « l'angle d'entrée médian de pale > l'angle d'entrée médian côté plaque principale de pale > l'angle d'entrée côté plaque latérale de pale ».
12. Turbosoufflante selon la revendication 11, dans laquelle à l'extrémité du bord d'attaque de pale (4a) dans une vue en plan, une différence d'angle ($\Delta\beta 1$) entre un angle d'entrée circonférentiel interne médian de pale qui est un angle d'entrée sur une extrémité latérale circonférentielle interne au milieu de la plaque latérale (3) et de la plaque principale (2) dans le sens de la hauteur et un angle d'entrée côté plaque latérale de pale qui est un angle d'entrée à une extrémité plus proche de la plaque latérale (3) est de 10 à 20 degrés.
13. Turbosoufflante selon la revendication 3, dans laquelle une rainure concave (5) est formée sur la surface circonférentielle interne de pale dans la région incurvée de la pale (4) de manière à s'étendre vers une extrémité proche de la plaque latérale (3), une ligne de pliage (B) est définie à une limite de la région incurvée et de la surface circonférentielle interne de pale à l'exception de la région incurvée, et la rainure concave (5) est sensiblement parallèle à la ligne de pliage (B) ; dans laquelle, éventuellement, la rainure concave (5) présente une section rectangulaire et se réduit progressivement vers une extrémité proche de la plaque latérale (3).
14. Appareil de climatisation, dans lequel la turbosoufflante selon l'une quelconque des revendications 1 à 13 est montée, et une unité de perte de pression d'aération (12) est disposée au niveau d'une ouverture d'entrée d'air de la turbosoufflante.
15. Appareil de climatisation, dans lequel la turbosoufflante selon l'une quelconque des revendications 1 à 13 est montée, et une unité de perte de pression d'aération (12) est disposée au niveau d'une ouverture de sortie d'air de la turbosoufflante.

FIG. 1

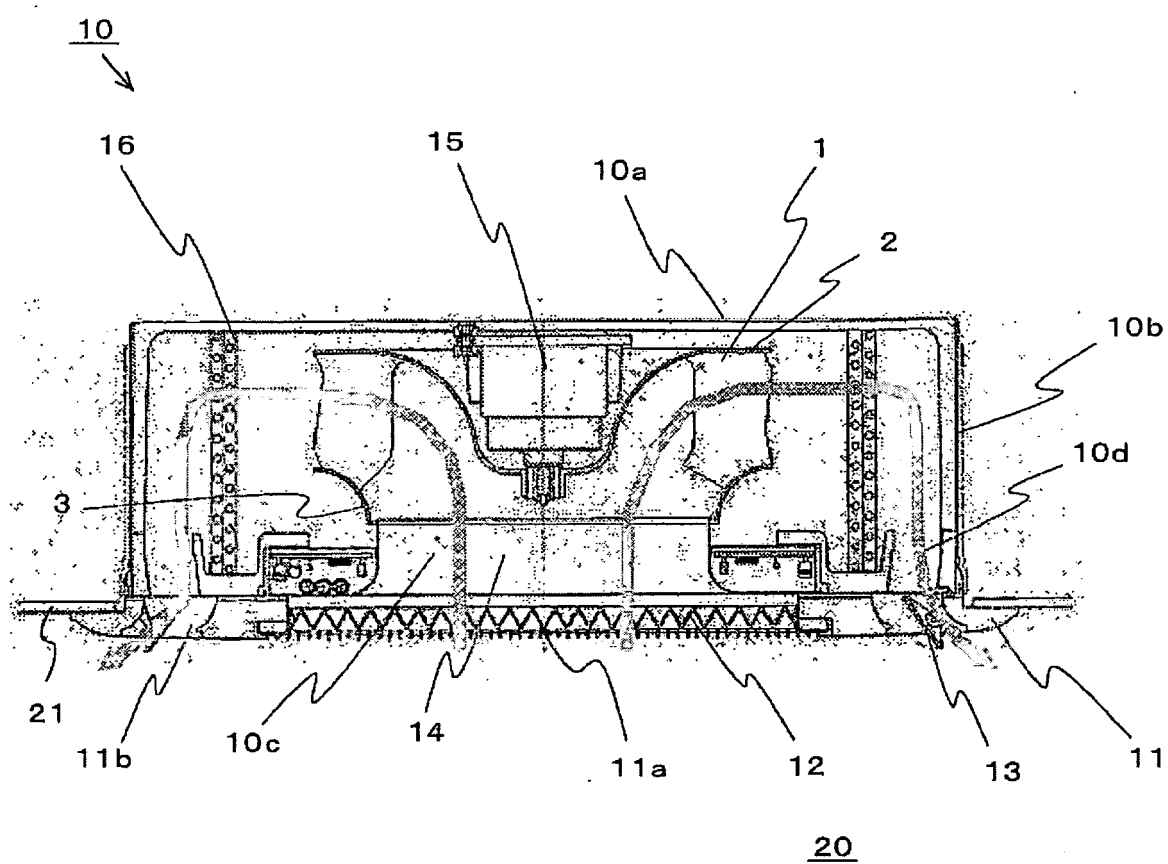


FIG. 2

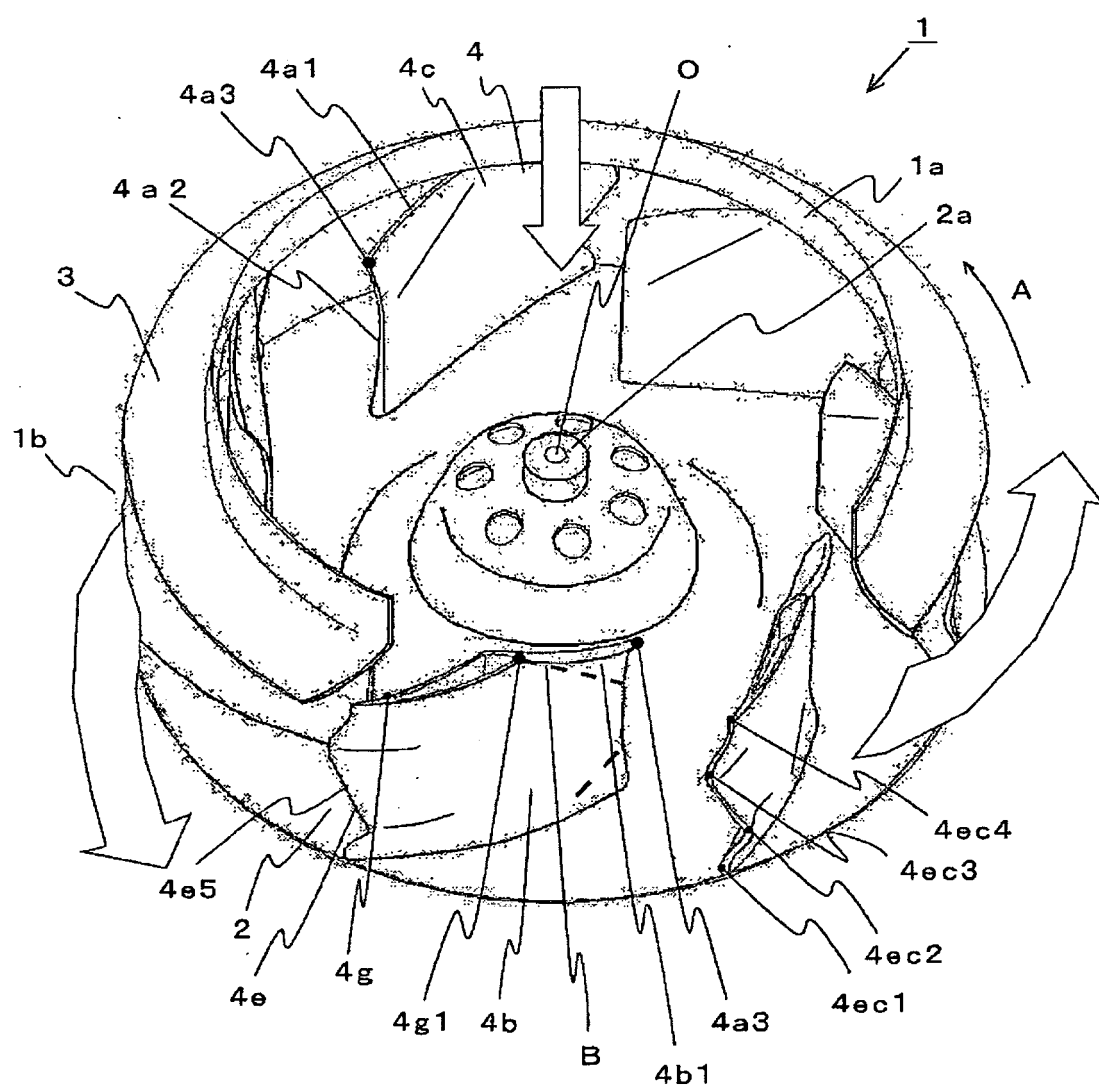


FIG. 3

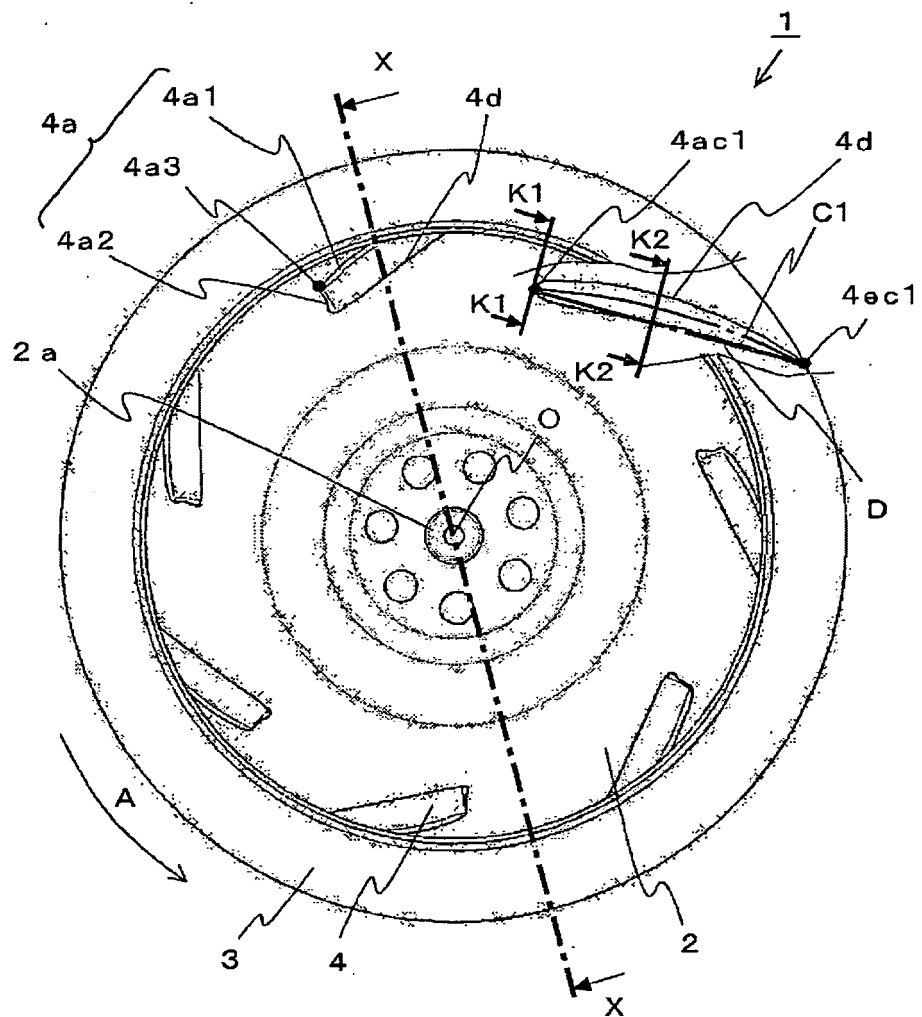


FIG. 4

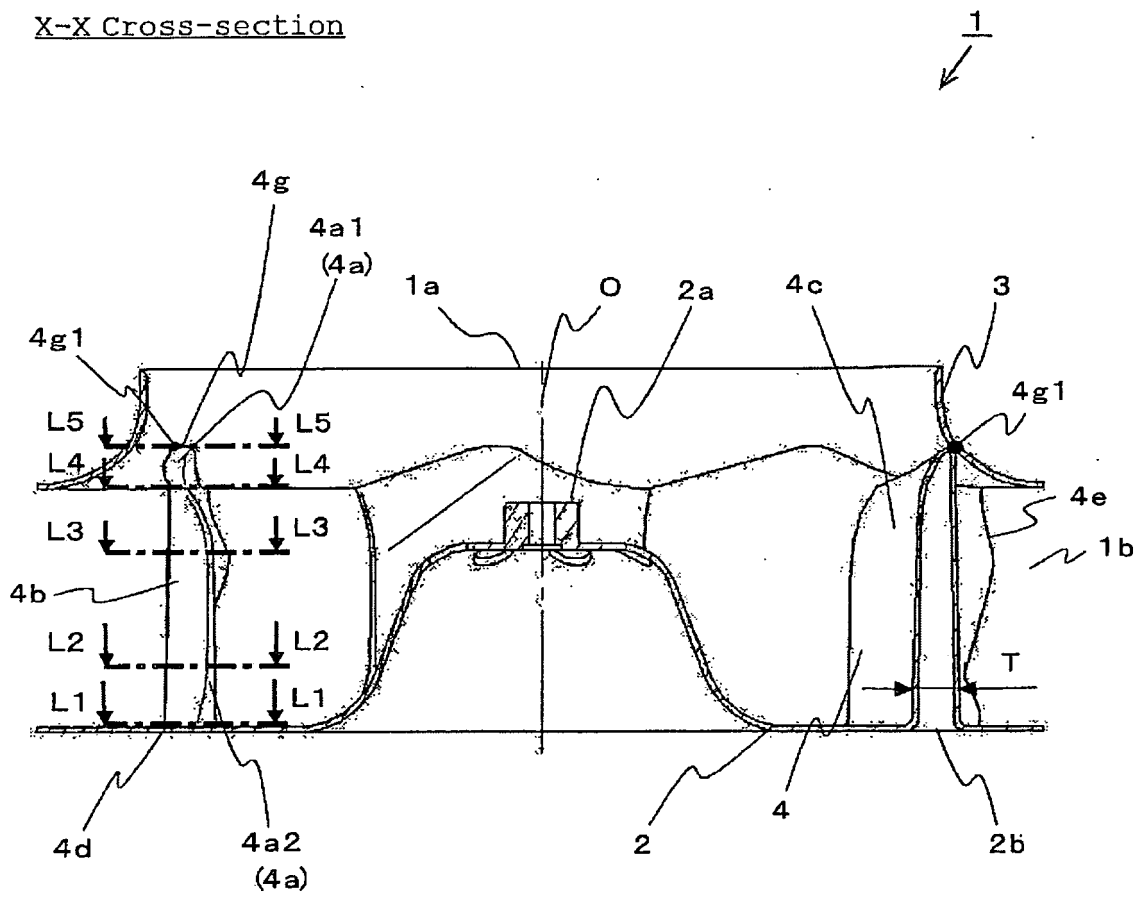


FIG. 5

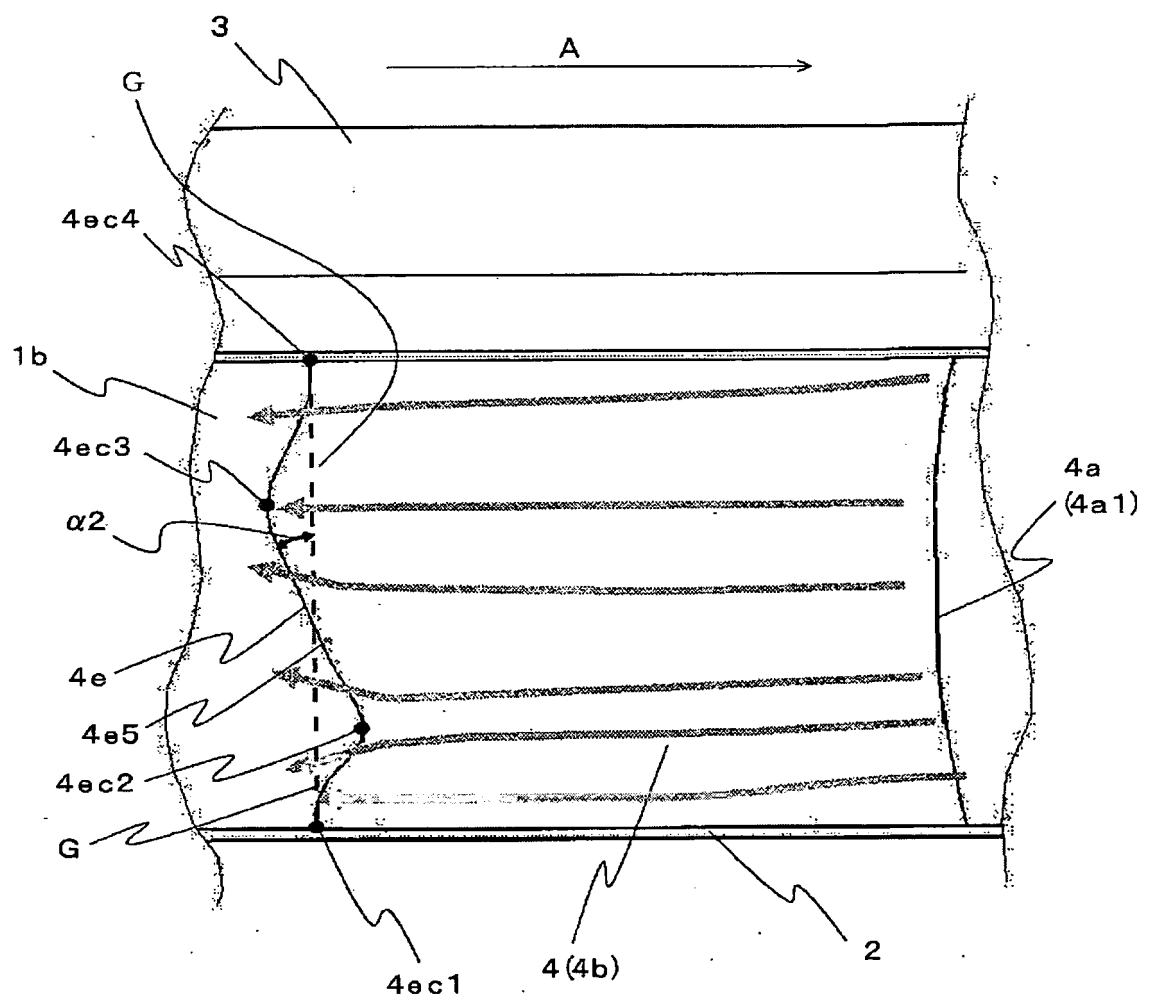


FIG. 6

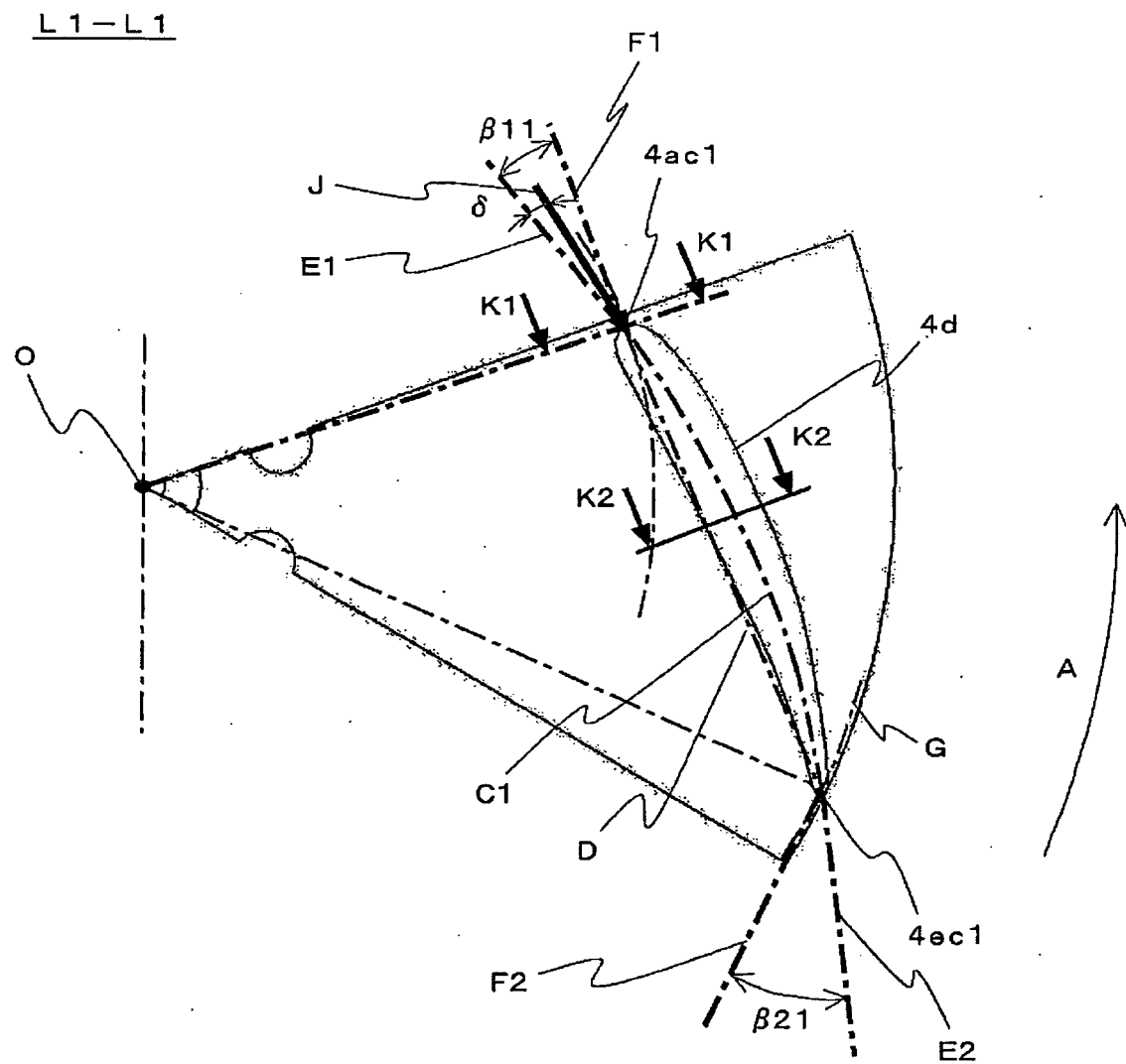


FIG. 7

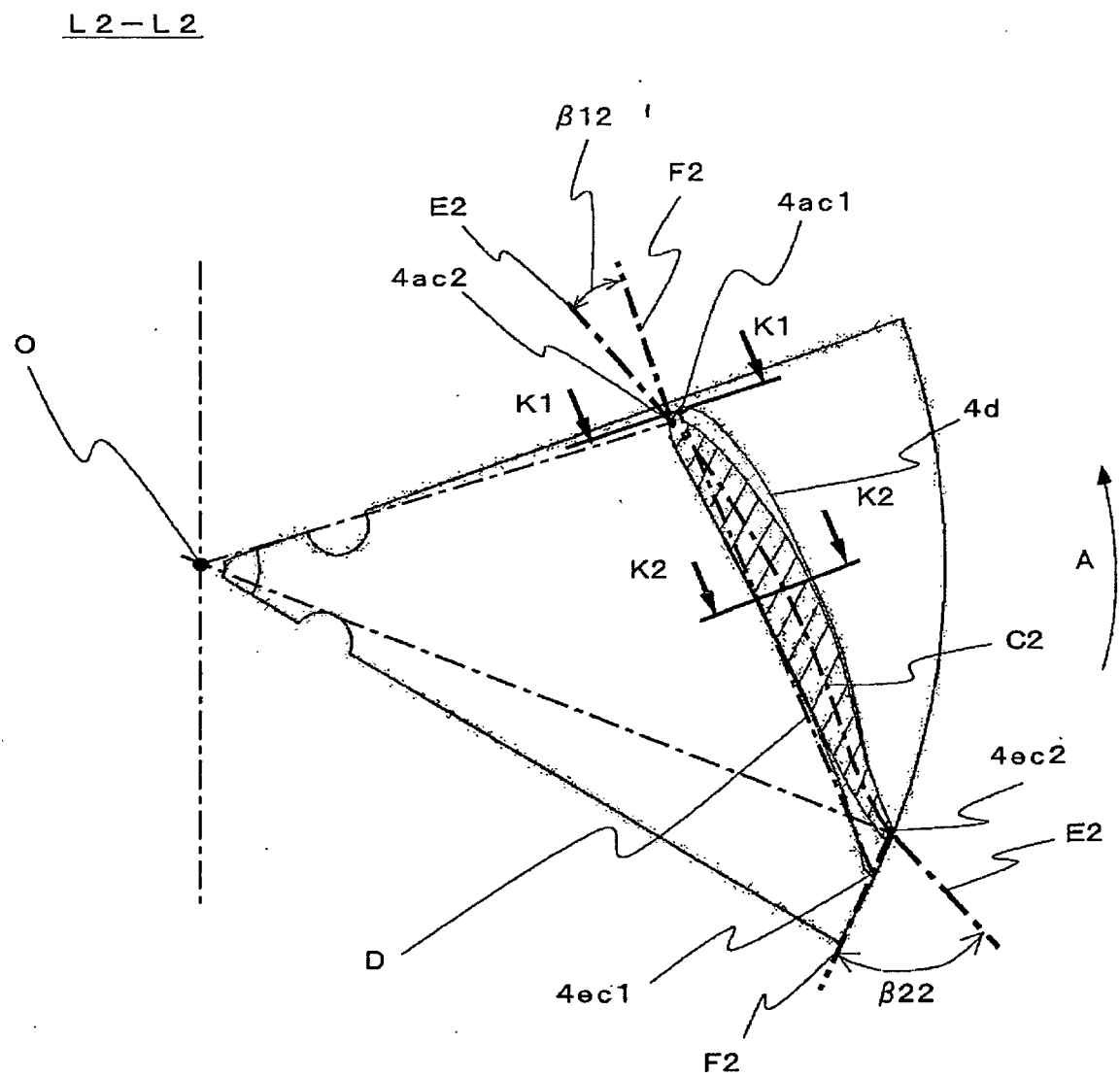


FIG. 8

L3-L3

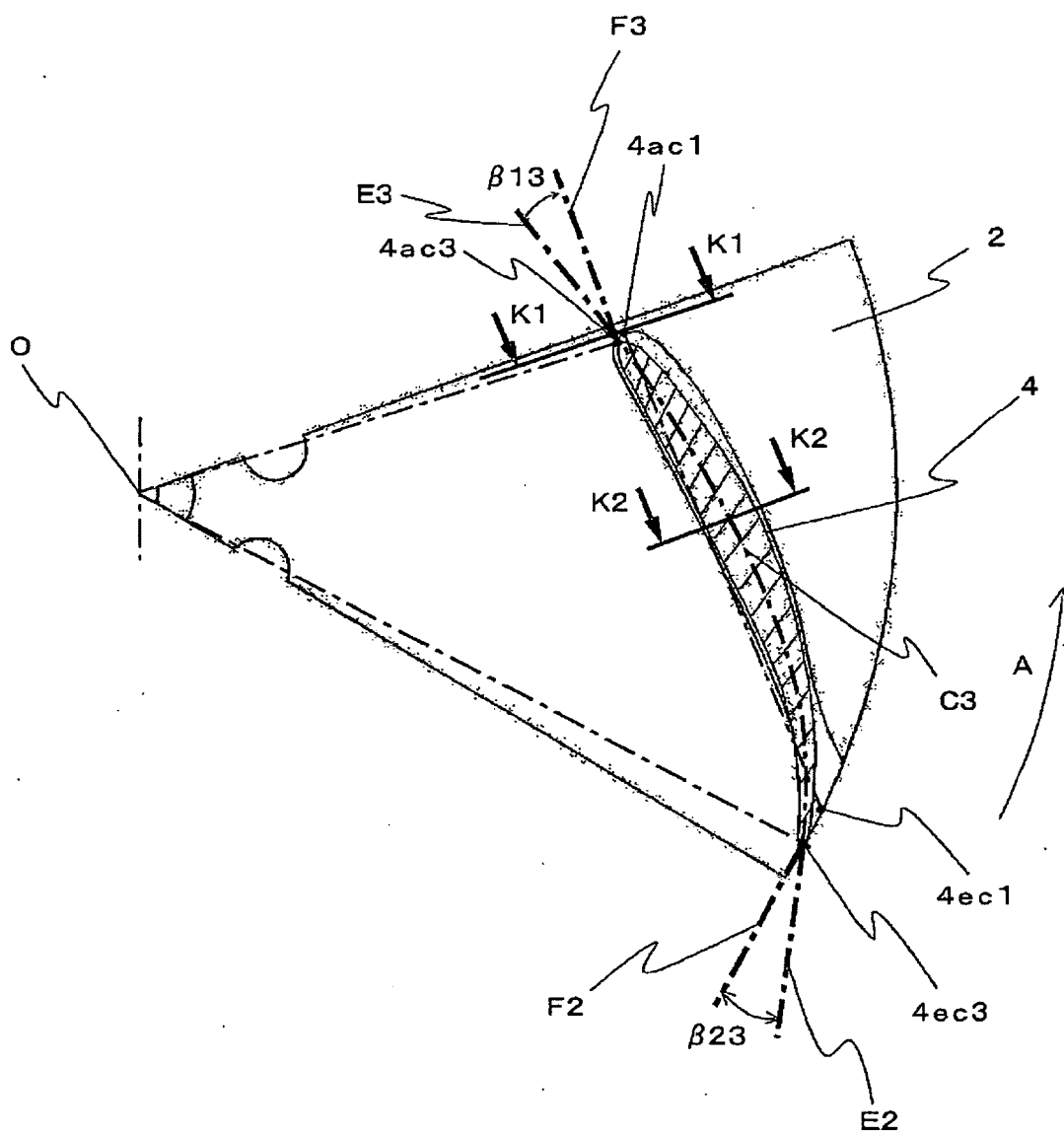


FIG. 9

L4-L4

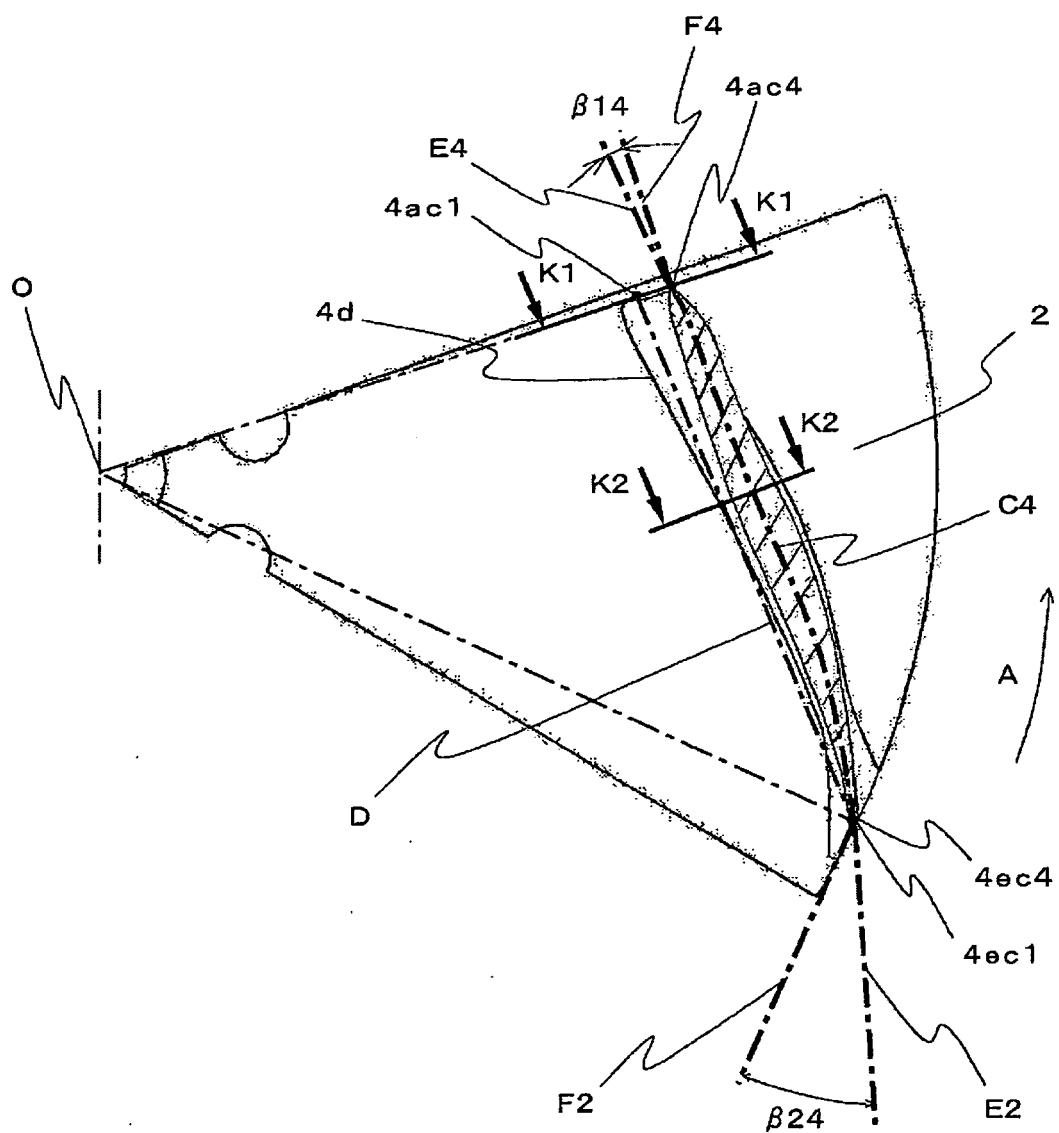


FIG. 10

L5-L5

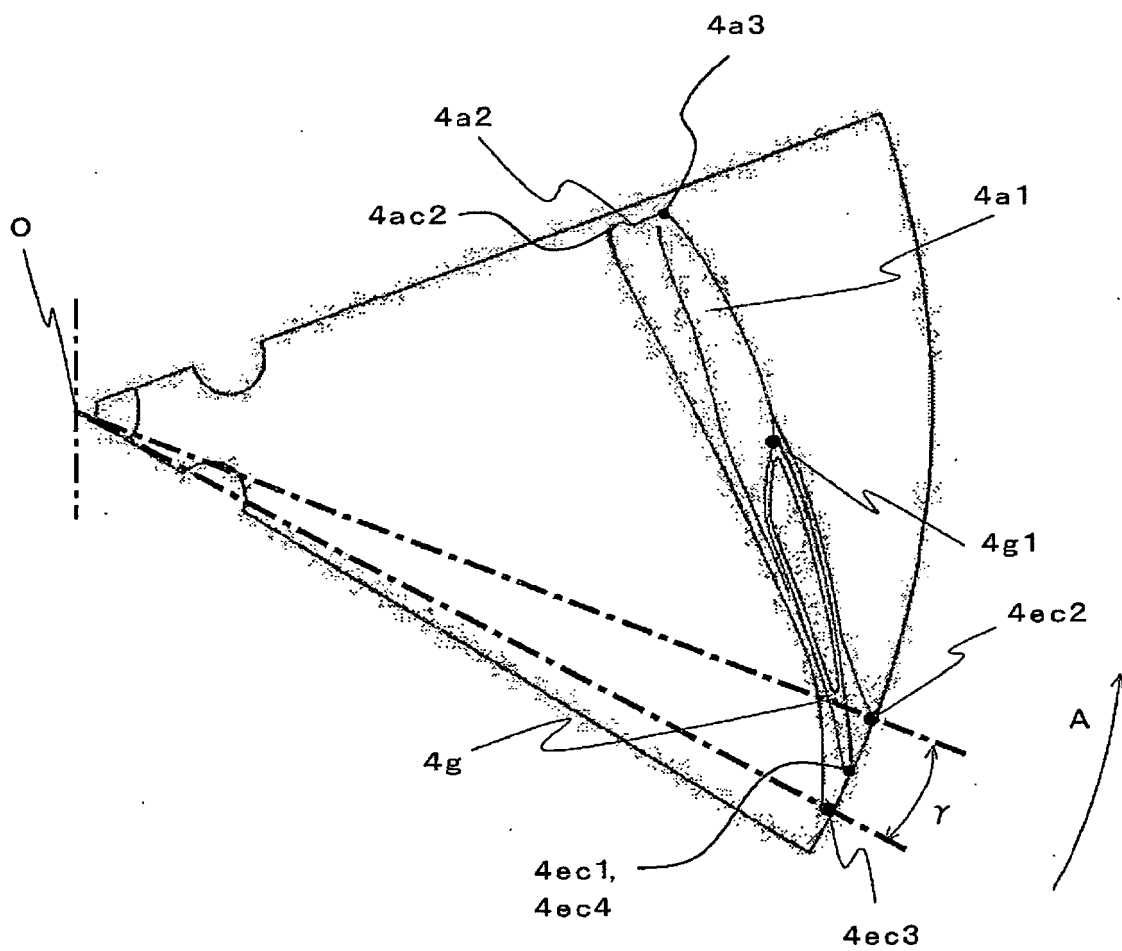


FIG. 11

K1-K1

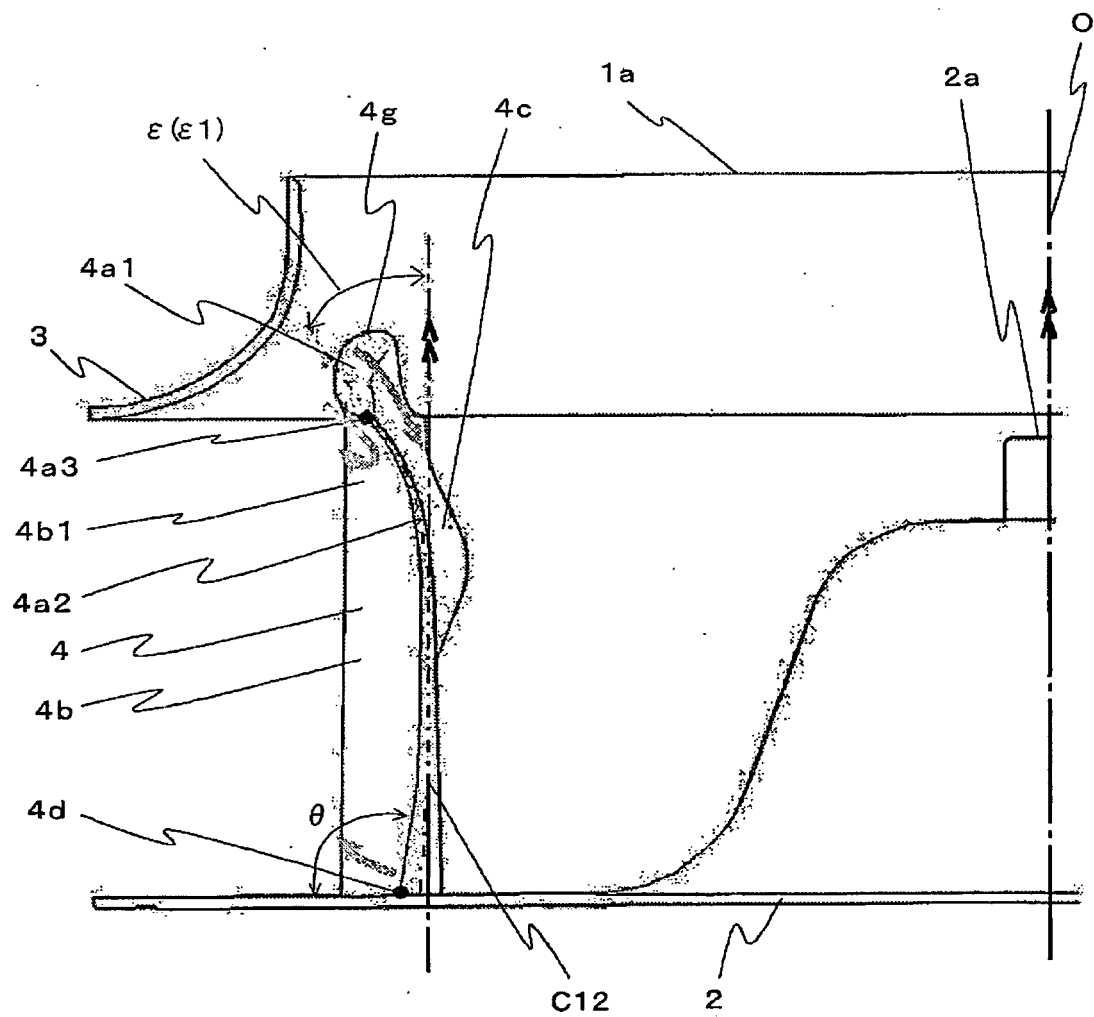


FIG. 12

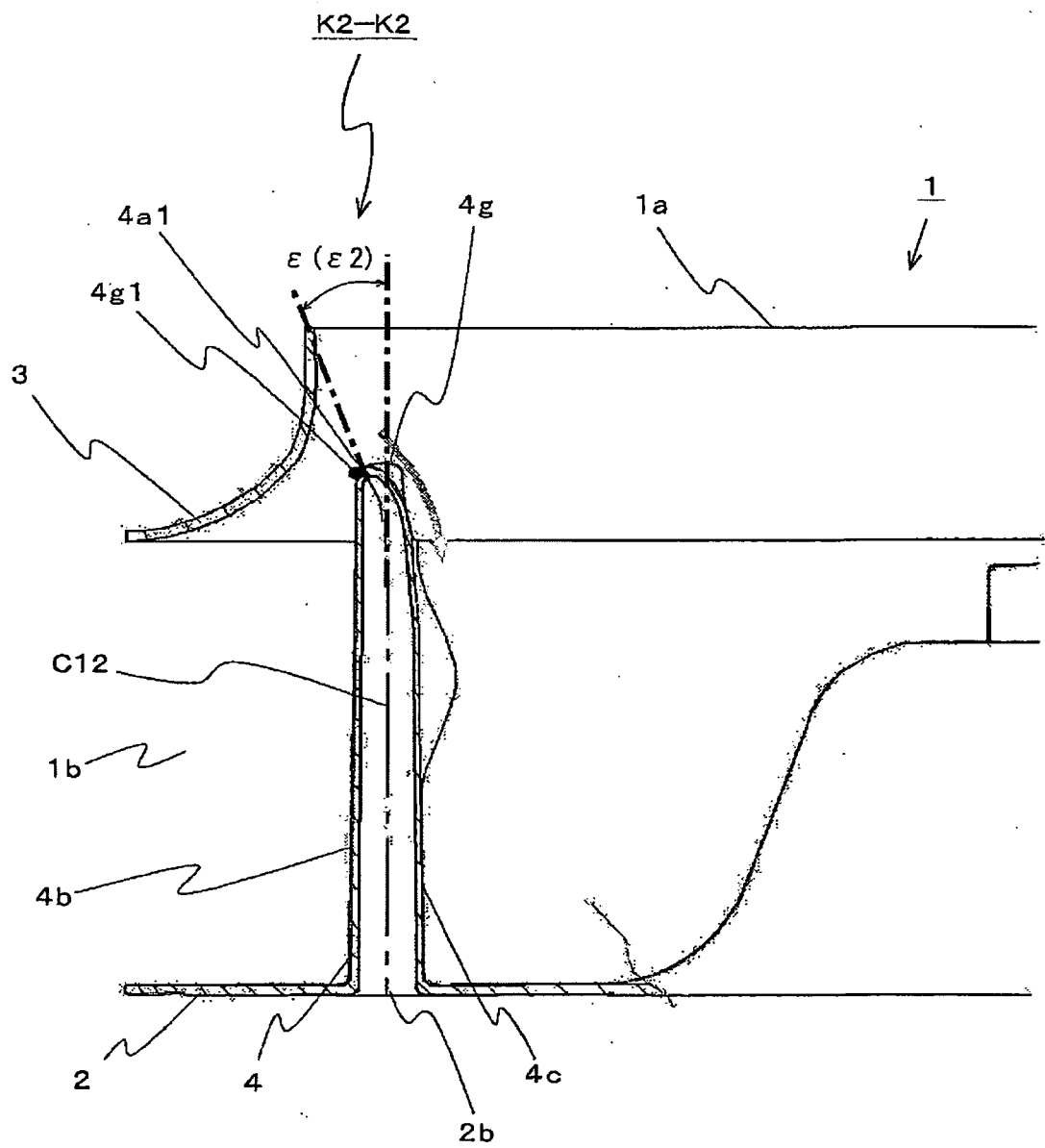


FIG. 13

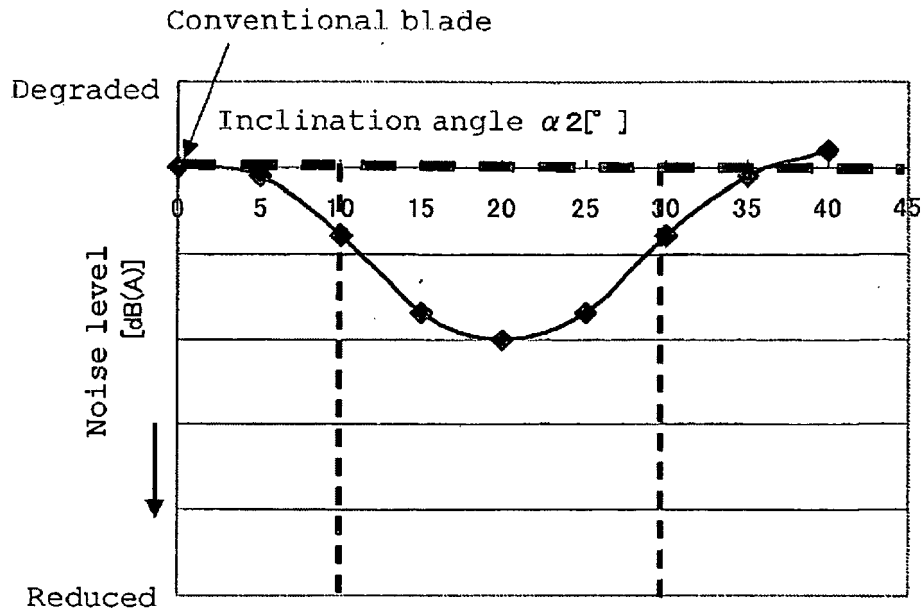


FIG. 14

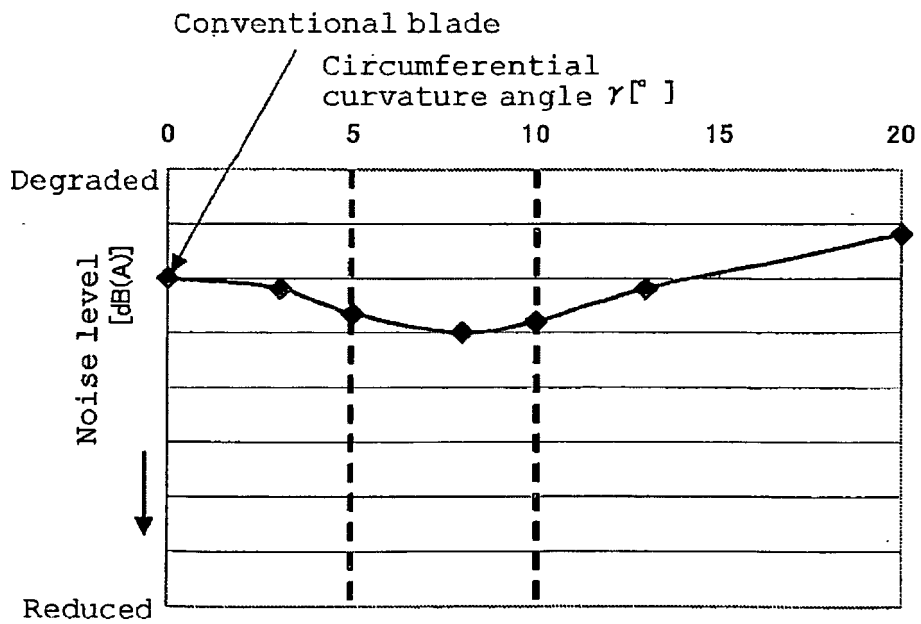


FIG. 15

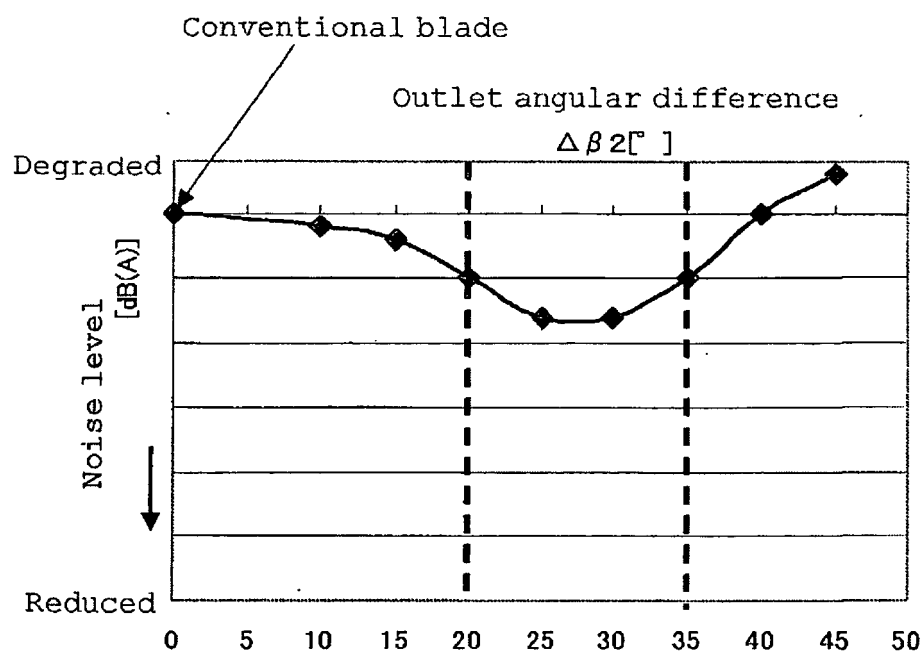


FIG. 16

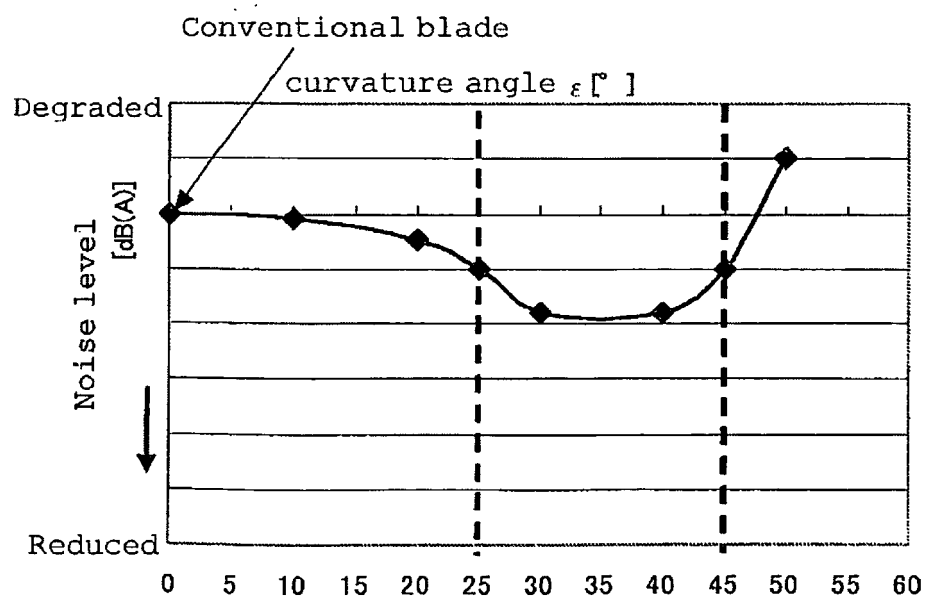


FIG. 17

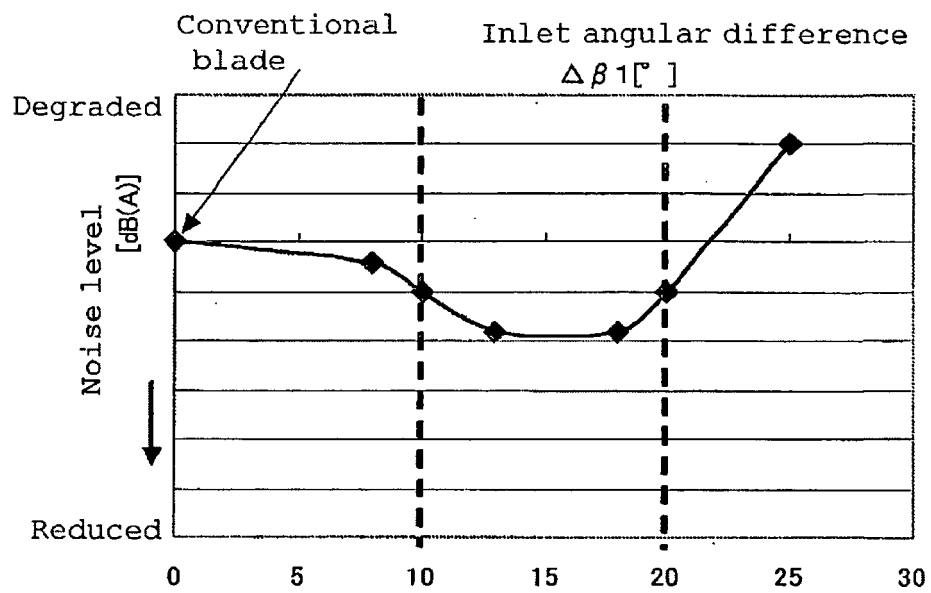


FIG. 18

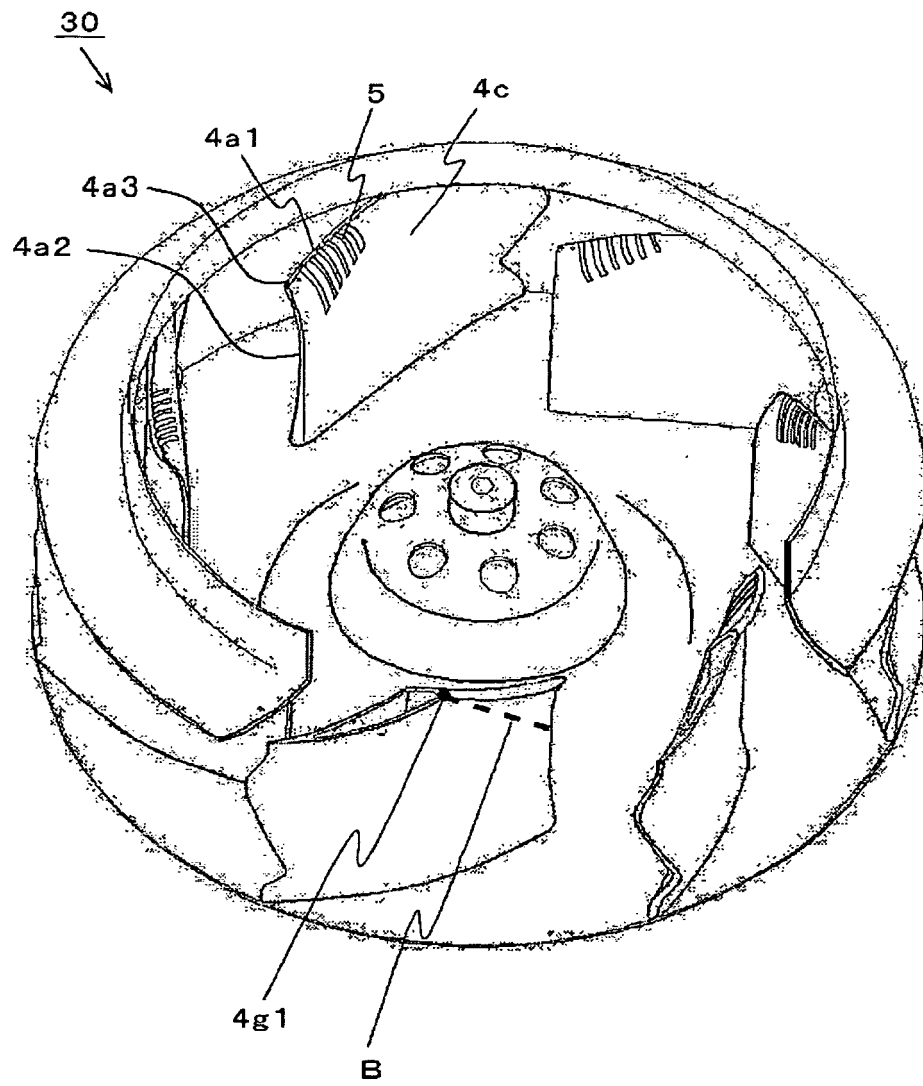
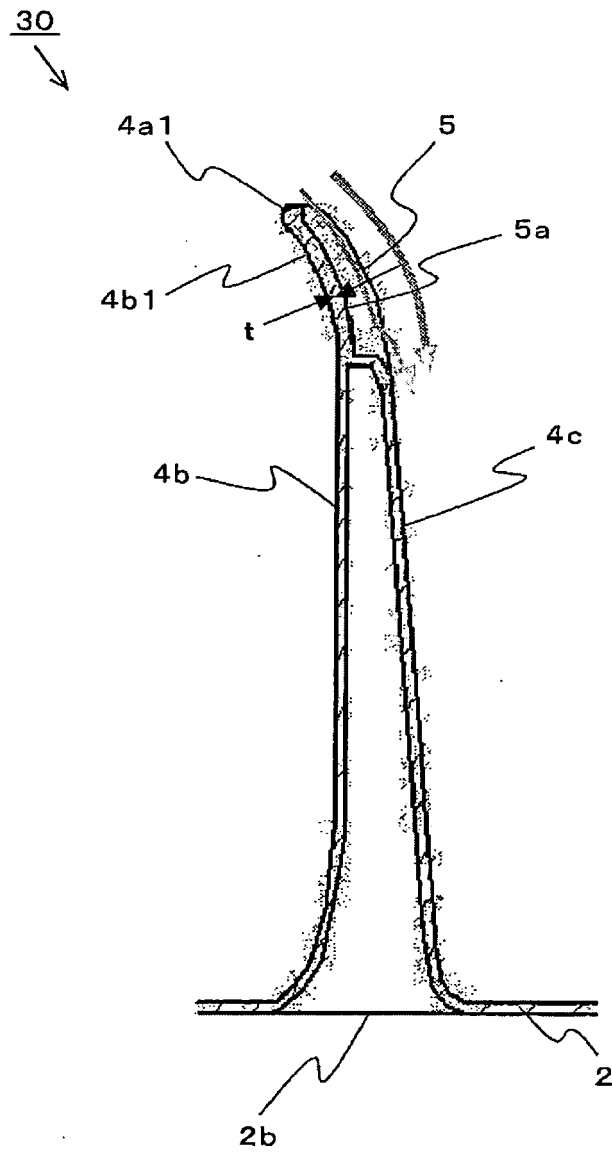


FIG. 19



REFERENCES CITED IN THE DESCRIPTION

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