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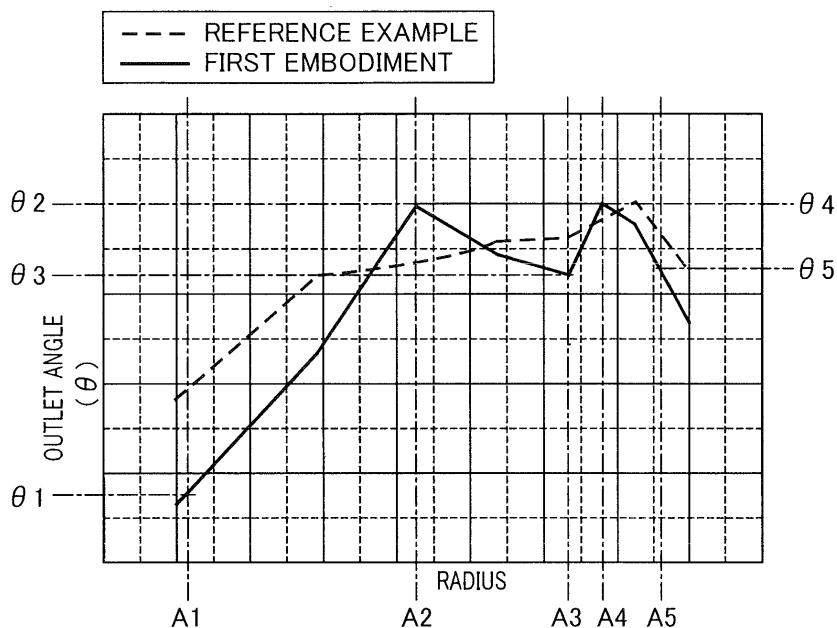
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(54) **PROPELLER FAN AND AIR CONDITIONER EQUIPPED WITH SAME**

(57) A propeller fan (4) includes a blade (12). The blade (12) has a shape in which a peak outlet angle (θ) at a trailing edge (15) thereof exists in an outer region (12B) of the blade that is located radially outer than the representative square mean radius position (R_r), and an

another peak outlet angle (θ) at a trailing edge (15) thereof exists in an inner region (12A) of the blade that is located radially inner than the representative square mean radius position (R_r).

FIG. 3



Description

Technical Field

[0001] The present invention relates to a propeller fan and an air conditioner including the same.

Background Art

[0002] Conventionally, there are known propeller fans for use in an air conditioner and the like. Rotation of the propeller fan generates airflow (leakage flow) in the vicinity of an outer peripheral portion of a blade, the airflow passing from a pressure surface side of the blade where pressure is high to a suction surface side of the blade where pressure is low. The airflow causes vortex flows (wing tip vortexes) in the vicinity of the outer peripheral portion of the blade. Such a wing tip vortex is liable to cause noise.

[0003] In a propeller fan of Patent Literature 1, an outer peripheral portion of a blade is provided with a bent portion for stabilizing a wing tip vortex, thereby attempting to reduce noise.

[0004] However, sufficient noise reduction effect is not always obtained by merely providing a bent portion in an outer peripheral portion of a blade as in Patent Literature 1.

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Translation of PCT International Application Publication (Tokuhyo) No. 2003-072948

Summary of Invention

[0006] The present invention aims to provide a propeller fan capable of reducing noise.

[0007] A propeller fan of the present invention includes a blade. The blade has a shape in which a peak outlet angle at a trailing edge thereof exists in an outer region of the blade that is located radially outer than the representative square mean radius position, and another peak outlet angle at a trailing edge thereof exists in an inner region of the blade that is located radially inner than the representative square mean radius position.

Brief Description of Drawings

[0008]

FIG. 1 is a sectional view showing a general structure of an outdoor unit of an air conditioner according to an embodiment of the present invention.

FIG. 2 is a front view of a propeller fan according to a first embodiment of the present invention.

FIG. 3 is a graph showing a relationship between radii and outlet angles at a trailing edge in each of propeller fans.

FIG. 4A is a front view of a blade of the propeller fan according to the first embodiment showing five radius lines A1 to A5 which correspond to the five radii A1 to A5 shown in the graph of FIG. 3. FIG. 4B is a front view of a blade of a propeller fan of a reference example showing five radius lines A1 to A5 which correspond to the five radii A1 to A5 shown in the graph of FIG. 3.

FIG. 5 is a diagram for explaining a representative square mean radius position of the propeller fans.

FIG. 6 is a circumferential sectional view of the blade. FIGS. 7A and 7B are sectional views taken along the line VIIA-VIIA in FIG. 4A. FIG. 7C is a sectional view taken along the line VIIC-VIIC in FIG. 4B.

FIG. 8A is a perspective view showing airflow in the propeller fan according to the first embodiment. FIG. 8B is a schematic view illustrating the airflow.

FIG. 9A is a perspective view showing airflow in the propeller fan of the reference example. FIG. 9B is a schematic view illustrating the airflow.

FIGS. 10A and 10B are graphs each comparing a property of the propeller fan according to the first embodiment with a corresponding property of the propeller fan of the reference example. FIG. 10A shows a relationship between air quantities and blowing loudnesses. FIG. 10B shows a relationship between air quantities and fan motor inputs.

FIG. 11A is a front view showing a part of a propeller fan according to a second embodiment of the present invention. FIG. 11B is a sectional view taken along the line XIB-XIB in FIG. 11A.

Description of Embodiments

<Overall Structure of Air Conditioner>

[0009] Hereinafter, a propeller fan according to an embodiment of the present invention and an air conditioner including the same will be described with reference to the accompanying drawings. FIG. 1 is a sectional view showing a general structure of an outdoor unit 1 of an air conditioner according to an embodiment of the present invention. The air conditioner includes the outdoor unit 1 shown in FIG. 1 and an unillustrated indoor unit. The outdoor unit 1 includes an outdoor heat exchanger 3, a propeller fan 4, a motor 5 and an unillustrated compressor, which are placed in a casing 2. The indoor unit includes unillustrated expansion mechanism and indoor heat exchanger, for example. The compressor, the outdoor heat exchanger 3, the expansion mechanism, the indoor heat exchanger, and an unillustrated refrigerant pipe connecting these components constitute a refrigerant circuit of the air conditioner.

[0010] In the outdoor unit 1 shown in FIG. 1, the outdoor heat exchanger 3 is provided at the back surface side of

the casing 2, and a discharge port 7 is provided at the front surface side of the casing 2. However, the invention is not limited to this configuration. For example, in the outdoor unit 1, the discharge port 7 may be provided in a top portion of the casing 2. The discharge port 7 is provided with a fan guard 7a in the form of a grill.

[0011] The propeller fan 4 is located inside the discharge port 7 of the casing 2. The propeller fan 4 is connected to a shaft 5a of the motor 5, and is driven to rotate around a rotation axis A0 by the motor 5. In the present embodiment, the rotation axis A0 of the propeller fan 4 lies in a forward-backward direction (horizontal direction). However, the invention is not limited to this configuration. The rotation axis A0 may lie in a direction oblique to the horizontal direction, for example. Alternatively, in the case where the discharge port 7 is provided in the top portion of the casing 2 in the outdoor unit 1, for example, the rotation axis A0 of the propeller fan 4 may lie in a top-bottom direction (vertical direction).

[0012] In the casing 2, a bell mouth 6 surrounding the outer circumference of the propeller fan 4 is provided. The bell mouth 6 is disposed between a region X (suction region X) that lies upstream of the propeller fan 4 in a direction of airflow and a region Y (discharge region Y) that lies downstream of the propeller fan 4 in the airflow direction. The bell mouth 6 is in the form of a ring and extends around the propeller fan 4 for guiding air that has passed through the outdoor heat exchanger 3 to the discharge port 7. The bell mouth 6 is slightly spaced from the propeller fan 4 so as not to be in contact with the propeller fan 4.

[0013] The propeller fan 4, the motor 5, and the bell mouth 6 constitute an axial flow blower 8. Rotation of the propeller fan 4 driven by the motor 5 of the axial flow blower 8 generates a pressure difference between the suction region X and the discharge region Y, which generates airflow passing from the suction region X to the discharge region Y.

<First Embodiment>

[0014] FIG. 2 is a front view of a propeller fan 4 according to a first embodiment of the present invention. The propeller fan 4 includes a hub 11 and a plurality of blades 12. In the present embodiment, the propeller fan 4 includes three blades 12. However, the invention is not limited to this configuration, and the propeller fan 4 may alternatively include two blades 12 or four or more blades 12. In the present embodiment, the hub 11 and the plurality of blades 12 are integrally molded. However, the invention is not limited to this configuration, and a plurality of components may be individually molded and then bonded together to form the propeller fan 4.

[0015] The hub 11 is generally in the form of a cylinder, a truncated cone or the like, but is not limited to these shapes. The hub 11 has an outer circumferential surface 11a joining the plurality of blades 12. The plurality of blades 12 are disposed at regular intervals along the out-

er circumferential surface 11a of the hub 11. In the case where the hub 11 is in the form of a cylinder, for example, the hub 11 has a substantially uniform outer diameter. However, in the case where the hub 11 is in the form of a truncated cone, for example, the outer diameter thereof increases or decreases toward the rotation axis A0. Further, the hub 11 may be in the form of a combination of a cylinder and a truncated cone, for example, or may have another shape. The rotation axis A0 of the propeller fan 4 lies at the center of the hub 11.

[0016] Each of the blades 12 includes an inner peripheral portion 13 located at radially inner side (hub 11 side) and connected to the hub 11, a leading edge 14 located at front side in a rotational direction D, a trailing edge 15 located at rear side in the rotational direction D (reverse side in the rotational direction D), and an outer peripheral portion 16 located at radially outer side. The blade 12 has a twisted shape in which the leading edge 14 is totally located at the side of the suction region X in comparison with the trailing edge 15. Further, the blade 12 has a pressure surface 21 located at the side of the discharge port 7 (the side of the discharge region Y), and a negative pressure surface 22 (see FIG. 6) located at the opposite side of the pressure surface 21 (the side of the suction region X).

[0017] As shown in FIG. 2, the outer peripheral portion 16 includes a bent portion 17 at which an end of the blade 12 is bent on the suction surface 22 (toward the suction region X), and an outer peripheral edge 18 defining a radially outer edge of the blade 12. The outer peripheral portion 16 has a width extending from the bent portion 17 to the outer peripheral edge 18. The bent portion 17 makes it possible to prevent vortexes from occurring in the vicinity of the outer peripheral portion 16 of the blade 12.

[0018] The bent portion 17 extends from the leading edge 14 (or the vicinity of the leading edge 14) to the trailing edge 15. In the present embodiment, the width of the outer peripheral portion 16 (distance between the bent portion 17 and the outer peripheral edge 18) increases toward the trailing edge 15. However, the invention is not limited to this configuration. Further, the bent portion 17 may be omitted, in which case, the outer peripheral portion 16 is defined by the outer peripheral edge 18.

(Outlet Angles of Trailing Edge)

[0019] Now, outlet angles θ at the trailing edge 15, which is a feature of the propeller fan 4 of the first embodiment, will be described. In the graph shown in FIG. 3, the solid line indicates a relationship between radii and outlet angles θ at the trailing edge 15 of the propeller fan 4 of the first embodiment shown in FIGS. 2 and 4A, and the broken line indicates a relationship between radii and outlet angles θ at a trailing edge 115 of a propeller fan 104 of a reference example shown in FIG. 4B.

[0020] The propeller fan 104 of the reference example will be briefly described. The propeller fan 104 of the ref-

erence example includes a hub 111 and three blades 112. Each of the blades 112 includes an inner peripheral portion 113, a leading edge 114, a trailing edge 115, and an outer peripheral portion 116 (a bent portion 117 and an outer peripheral edge 118). Further, the blade 112 has a pressure surface 121 and a negative pressure surface 122 (see FIG. 7C).

[0021] As shown in FIG. 3, at the trailing edge 15 of the blade 12 of the propeller fan 4 of the first embodiment, a plurality of peak outlet angles θ exist. Specifically, two peak outlet angles θ exist at the trailing edge 15 of the blade 12. One of the peak outlet angle at the trailing edge 15 exists in the outer region 12 that is located radially outer than the representative square mean radius position. The other of the peak outlet angle at the trailing edge 15 exists in the inner region 12A that is located radially inner than the representative square mean radius position.

[0022] It should be noted that, in the present embodiment, the peak does not necessarily refer to a maximum value of the outlet angles. Specifically, in such a graph as shown in FIG. 3, all of the outlet angles corresponding to the vertices of a polygonal part convexed upward are peak outlet angles. Therefore, one blade 12 may have a plurality of peak outlet angles that are different from one another at the trailing edge 15.

[0023] In contrast, the blade 12 of the reference example shown in FIG. 4B has only one peak outlet angle θ at the trailing edge 15. The peak outlet angle θ is disposed at the trailing edge 115 in an outer region of the blade 112 which is located radially outer than the representative square mean radius position R_r . The blade 112 of the reference example has progressively greater outlet angles θ from the inner peripheral portion 113 toward the outer peripheral portion 116 at the trailing edge 115, the peak outlet angle θ being disposed in the outer region located radially outer than the representative square mean radius position (at a position close to the outer peripheral portion 116).

[0024] The representative square mean radius position R_r bisects a flow area of the propeller fan 4 (104) into a central side portion (hub side portion) and an outer peripheral side portion. FIG. 5 is a diagram for explaining the representative square mean radius position R_r of the propeller fan 4 (104). The representative square mean radius position R_r is calculated by the following formula (1) wherein "R" represents a representative radius of the blade 12 (112) and "r" represents a representative radius of the hub 11 (111).

[0025] representative square mean radius position

$$R_r = ((R^2 + r^2) / 2)^{0.5} \dots (1)$$

[0026] The representative radius R of the blade is calculated as follows.

[0027] In the case where the outer diameter of the

blade is uniform along the rotation axis, the representative radius R of the blade is equal to a half of the outer diameter.

[0028] In the case where the outer diameter of the blade is not uniform along the rotation axis, the representative radius R of the blade is calculated as follows. The representative radius R of the blade is equal to the mean value of a minimum blade radius R1 and a maximum blade radius R2 ($R = (R1 + R2) / 2$).

[0029] The representative radius r of the hub is, in the case where the outer diameter of the hub is uniform along the rotation axis, equal to a half of the outer diameter.

[0030] In the case where the outer diameter of the hub is not uniform along the rotation axis, for example, in the case of the hub being in the form of a truncated cone, the representative radius r of the hub is calculated as follows.

[0031] The representative radius r of the hub is equal to the mean value of a minimum hub radius r1 and a maximum hub radius r2 ($r = (r1 + r2) / 2$).

[0032] Five radii A1 to A5 shown in FIG. 3 correspond to radius lines A1 to A5 shown in FIGS. 4A and 4B. For example, the radius line A1 is on the blade 12 (112) and a part of a circle having the radius A and centered on the rotation axis A0, in a front view of the propeller fan, as shown in FIGS. 4A and 4B. The same description is applicable to the radius lines A2 to A5, and is therefore omitted.

[0033] In the first embodiment and the reference example shown in FIGS. 4A and 4B, the radius line A3 lies on the representative square mean radius position R_r . However, the invention is not limited to this configuration. The radius line A3 bears an outlet angle θ_3 having a minimum value between the two peak outlet angles. The radius lines A1 and A2 are located in the inner region 12A that is located at the side of the hub 11 than radius line A3. The radius lines A4 and A5 are located in the outer region 12B that is located at the side of the outer peripheral portion 16 than radius line A3.

[0034] FIG. 6 is a circumferential sectional view of the blade 12 (for example, a sectional view taken along the radius line A3 shown in FIG. 4). In the sectional view shown in FIG. 6, an outlet angle θ at the trailing edge 15 is defined by an angle between a tangent line L3 contacting to the pressure surface 21 at the trailing edge 15 and a straight line L4 perpendicularly intersecting the rotation axis A0 of the propeller fan 4.

[0035] In the first embodiment, as shown in FIG. 3, the peak outlet angle θ in the inner region 12A, in other words, the outlet angle θ having a maximum value in the inner region 12A, is an outlet angle θ_2 at the radius A2 (first peak position). The peak outlet angle θ in the outer region 12B, in other words, the outlet angle having a maximum value in the outer region 12B, is an outlet angle θ_4 at the radius A4 (second peak position).

[0036] The outlet angle θ_3 at the radius A3 is smaller than the outlet angles θ_2 and θ_4 . In the present embodiment, the outlet angle θ having a minimum value be-

tween the two peak outlet angles (between the radius A2 and the radius A4) is the outlet angle θ_3 at the representative square mean radius position R_r (radius A3). However, the invention is not limited to this configuration. The outlet angle θ having a minimum value between the two peak outlet angles may be located at a position shifted from the representative square mean radius position R_r .

[0037] In the present embodiment, the outlet angles θ progressively increase from the inner peripheral portion 13 to the radius A2 and progressively decrease from the radius A4 to the outer peripheral portion 16 (bent portion 17) at the trailing edge 15. Further, the outlet angles θ progressively decrease from the radius A2 to the radius A3 and progressively increase from the radius A3 to the radius A4 at the trailing edge 15. In other words, the outlet angles θ at the trailing edge 15 change in a substantially M-shaped curve as shown in FIG. 3.

[0038] A specific example of differences between the outlet angles θ_2 and θ_4 at the peak radii and the outlet angle θ_3 located therebetween and having a minimum value is provided as follows. The difference between the outlet angle θ_2 and the outlet angle θ_3 may be set to fall within the range from 0.5 to 10 degrees or the range from 1 to 5 degrees, for example. The difference between the outlet angle θ_4 and the outlet angle θ_3 may be set to fall within the range from 0.5 to 10 degrees or the range from 1 to 5 degrees, for example.

[0039] The embodiment shown in FIG. 3 shows an example in which the outlet angle θ_2 at the radius A2 (first peak position) and the outlet angle θ_4 at the radius A4 (second peak position) have the same value. However, the invention is not limited to this configuration. The outlet angles θ_2 and θ_4 may have different values. Specifically, the outlet angle θ_2 may be greater or smaller than the outlet angle θ_4 .

(Radii of Curvature of Pressure Surface)

[0040] Now radii of curvature of the pressure surface 21, which is another feature of the propeller fan 4 of the first embodiment will be described. FIGS. 7A and 7B are sectional views taken along the line VIIA-VIIA in FIG. 4A. FIGS. 7A and 7B are sectional views obtained by cutting the propeller fan 4 of the first embodiment at a plane including the rotation axis A0. FIG. 7C is a sectional view taken along the line VIIC-VIIC in FIG. 4B. FIG. 7C is a sectional view obtained by cutting the propeller fan 104 of the reference example at a plane including the rotation axis A0.

[0041] As shown in FIG. 7A, in the propeller fan 4 of the first embodiment, a pressure surface 21A in the inner region 12A (inner pressure surface 21 A) has a concave curve surface, and a pressure surface 21B in the outer region 12B (outer pressure surface 21B) has an another concave curve surface. In the present embodiment, the outer pressure surface 21B is located at the region between the representative square mean radius position R_r and the bent portion 17 of the outer peripheral portion

16.

[0042] The concave curve surface of the inner pressure surface 21 A and the concave curve surface of the outer pressure surface 21B adjoin each other via the representative square mean radius position R_r . In other words, the concave curve surface of the inner pressure surface 21A and the concave curve surface of the outer pressure surface 21B are adjacently disposed to each other in a radial direction. As shown in FIG. 7A, a pressure surface 21C of the specific region that bears the representative square mean radius position R_r lying on the boundary between the adjoining two concave curve surfaces and the vicinity thereof is in the form of a convex curve surface.

[0043] The concave curve surface of the inner pressure surface 21A circumferentially extends from the leading edge 14 to the trailing edge 15 and, similarly, the concave curve surface of the outer pressure surface 21B circumferentially extends from the leading edge 14 to the trailing edge 15.

[0044] The inner pressure surface 21A may be entirely in the form of a concave curve surface, but is not limited to this shape. In the present embodiment, the inner pressure surface 21A has a concave curve surface in a region close to the representative square mean radius position R_r , but has a flat or substantially flat surface in a region close to the inner peripheral portion 13. The outer pressure surface 21B may be entirely in the form of a concave curve surface, but is not limited to this shape. In the present embodiment, the outer pressure surface 21B is substantially entirely in the form of a concave curve surface.

[0045] The negative pressure surface 22 extends along the pressure surface 21 in such a manner that the thickness of the blade 12 does not change much over the entire blade. Therefore, the negative pressure surface 22 has a convex curve surface on the opposite side of the concave curve surface of the pressure surface 21.

[0046] The inner pressure surface 21A has a maximum radius of curvature greater than a maximum radius of curvature of the outer pressure surface 21B. Further, the inner region 12A includes a negative pressure surface 22A (inner negative pressure surface 22A) having a maximum radius of curvature greater than a maximum radius of curvature of a negative pressure surface 22B (outer negative pressure surface 22B) of the outer region 12B. In other words, the inner pressure surface 21A is flatter than the outer pressure surface 21B. The flat shape of the inner pressure surface 21 A can also be described as follows.

[0047] In the sectional view shown in FIG. 7B, an imaginary straight line L5 is drawn from an end T1 of the pressure surface 21, the end joining the inner peripheral portion 13 to an intersection T2 of the pressure surface 21 with the characteristic root mean square radius line R_r . In addition, an imaginary straight line L6 is drawn from an end T3 of the pressure surface 21, the end joining the outer peripheral portion 16 (the bent portion 17 in the

present embodiment) to the intersection T2 of the pressure surface 21 with the representative square mean radius position Rr. In the first embodiment, a maximum value D1 in the varied distances between the imaginary straight line L5 and the pressure surface 21 (inner pressure surface 21 A) is smaller than a maximum value D2 in the varied distances between the imaginary straight line L6 and the pressure surface 21 (outer pressure surface 21B).

[0048] In the sectional view shown in FIG. 7B, the position that bears the maximum value D1 over the pressure surface 21 is disposed at a position closer to the intersection T2 than the end T1. In other words, the position that bears the maximum value D1 over the pressure surface 21 is disposed on the inner pressure surface 21A at a position closer to the representative square mean radius position Rr than the inner peripheral portion 13. In other words, in the blade 12, a portion that lies in the inner region 12A and is closer to the inner peripheral portion 13 is flatter (more planar) than a portion that lies in the inner region 12A and is closer to the outer peripheral portion 16 (representative square mean radius position Rr).

[0049] In contrast, in the propeller fan of the reference example shown in FIG. 7C, the pressure surface 121 of the blade 112 has a single large convex surface extending from the inner peripheral portion 113 to the bend 117 of the outer peripheral portion 116. The suction surface 122 on the opposite side of the pressure surface 121 has a shape corresponding to the pressure surface 121. In other words, the suction surface 122 has a single large convex surface extending from the inner peripheral portion 113 to the bend 117 of the outer peripheral portion 116.

[0050] As shown in FIG. 7C, the blade 112 of the reference example extends radially, and is curved more greatly in the direction of the rotation axis A0 than the blade 12 of the first embodiment, thereby having a solid shape. Specifically, in the sectional view shown in FIG. 7C, an imaginary straight line L11 is drawn from an end T11 of the pressure surface 121, the end joining the inner peripheral portion 113 to an end T12 of the pressure surface 121, the end joining the outer peripheral portion 116 (the bent portion 117 in this reference example). In this case, a maximum value D11 in the varied distances between the imaginary straight line L11 and the pressure surface 121 is considerably greater than the maximum values D1 and D2 in the first embodiment.

[0051] Therefore, in the reference example, each of the blades 112 has a large sectional area and, therefore, the entire propeller fan has large volume and weight compared to the first embodiment. Accordingly, the propeller fan of the reference example has problems in terms of resource saving, cost reduction, and the like.

[0052] Further, because the blade 112 of the reference example has a solid shape as described, it is liable to elastically deform due to a stress generated by rotation of the propeller fan. In other words, the blade 112 of the

reference example has a solid shape and includes many causing points of elastic deformation, and is therefore liable to elastically deform in a deformation mode in which the blade 112 is liable to elastically deform into a planar shape (deformation mode in which the blade 112 is liable to expand radially outward) during rotation. Accordingly, the blade 112 of the reference example requires reinforcement for preventing the elastic deformation, which results in a problem of an increased weight.

[0053] On the other hand, the propeller fan 4 of the first embodiment shown in FIGS. 7A and 7B includes, not a single large concave curve surface as in the reference example, but the combination of at least two concave curve surfaces as described above. As shown in FIG. 7B, in the first embodiment, each of the two concave curve surfaces has a peak depth (the maximum values D1 and D2). The depths D1 and D2 (maximum values D1 and D2) of the two concave curve surfaces of the first embodiment are smaller than the depth (maximum value D11) of the concave curve surface of the reference example. Further, the radial length of each of the concave curve surfaces of the first embodiment is smaller than the radial length of the concave curve surface of the reference example.

[0054] The blade 12 of the first embodiment having the above-described features is flatter (more planar) than the blade 112 of the reference example. The blade 12 of the first embodiment having such shape is allowed to have, in the case of having a thickness distribution from the inner peripheral portion 13 to the outer peripheral portion 16 similar to that of the blade 112 of the reference example, a smaller sectional area than the blade 112 of the reference example. This allows each of the blades 12 to have a small weight and, therefore, allows the entire propeller fan 4 to have a small volume and weight compared to the reference example.

[0055] Further, because the blade 12 of the first embodiment is flatter than the blade 112 of the reference example, it is unlikely to elastically deform due to a stress generated by rotation of the propeller fan 4. In other words, since the blade 12 of the first embodiment usually has a planar shape, the amount of an elastic deformation is small.

[0056] Further, in the present embodiment shown in FIG. 7A, the momentum of the air flowing along the pressure surface 21 locally changes greatly in the outer pressure surface 21B as shown by arrows in the figure. In contrast, in the reference example shown in FIG. 7C, the momentum of the air flowing along the pressure surface 121 changes over the entire pressure surface 121 as shown by arrows in the figure.

(Recessed portion of Trailing Edge)

[0057] Now a recessed portion 19 of the trailing edge 15, which is further another feature of the propeller fan 4 of the first embodiment will be described. As shown in FIG. 4A, the recessed portion 19 is provided on the trail-

ing edge 15 of the blade 12 of the first embodiment, the recessed portion being oriented toward the leading edge 14. The recessed portion 19 is provided in a region bearing the representative square mean radius position R_r . The recessed portion 19 is not an essential constituent and may be omitted. The recessed portion 19 has a substantially V-shape or a substantially U-shape in a front view, for example, but is not limited to these shapes.

[0058] The provision of the recessed portion 19 at the representative square mean radius position R_r on the trailing edge 15 where the pressure is liable to increase on the pressure surface 21 makes it possible to reduce a pressure rise at the representative square mean radius position R_r on the trailing edge 15. This allows the air flowing along the pressure surface 21 from the leading edge 14 toward the trailing edge 15 to move toward the hub 11 and to the outer peripheral portion 16 in such a manner as to avoid the representative square mean radius position R_r in the vicinity of the trailing edge 15. Therefore, the effect of guiding airflow in a circumferential direction can be enhanced. The effect of guiding airflow in the circumferential direction can be further enhanced by the combination of this effect of guiding airflow in the circumferential direction provided by the recessed portion 19, and the guiding effect provided by disposing the respective peak outlet angles θ in the hub 11-side region and the outer peripheral portion 16 side-region, the regions being on opposite sides of the representative square mean radius position R_r .

[0059] Further, in the present embodiment, a bottom 19a of the recessed portion 19 (leading part of the recessed portion 19 in the rotational direction D) lies at the representative square mean radius position R_r . However, the invention is not limited to this configuration. In the case where the bottom 19a of the recessed portion 19 lies at the representative square mean radius position R_r , the above-described guiding effect can be further enhanced.

(Airflow during Rotation)

[0060] Now airflow generated during rotation of the propeller fan 4 of the first embodiment will be described in comparison with the reference example. FIG. 8A is a perspective view showing airflow in the propeller fan according to the first embodiment, and FIG. 8B being a schematic view illustrating the airflow. FIG. 9A is a perspective view showing airflow in the propeller fan of the reference example, and FIG. 9B being a schematic view illustrating the airflow.

[0061] As shown in FIGS. 8A and 8B, in the propeller fan 4 of the first embodiment, the effect of guiding airflow in the circumferential direction is high especially in the inner region 12A. This restrains air from flowing to the outer peripheral portion 16.

[0062] In contrast, in the reference example shown in FIGS. 9A and 9B, there is a low effect of guiding airflow in a circumferential direction in the inner region. There-

fore, air is liable to flow to the outer peripheral portion 116.

[0063] Consequently, blowing loudness is considerably lower in the first embodiment than in the reference example, as shown in FIG. 10A. Furthermore, the first embodiment makes it possible to, while reducing blowing loudness, obtain an equal air quantity by a substantially equal fan motor input to those of the reference example as shown in FIG. 10B. In the first embodiment, reduction in weight is achieved without sacrificing blowing performance.

<Second Embodiment>

[0064] FIG. 11A is a front view showing a part of a propeller fan 4 according to a second embodiment of the present invention, and FIG. 11B being a sectional view taken along the line XIB-XIB in FIG. 11A.

[0065] The propeller fan 4 of the second embodiment differs from the first embodiment in that each of blades 12 has a solid shape similarly to the blade 112 of the reference example. Specifically, the blade 12 of the second embodiment includes, as shown in FIG. 11B, a pressure surface 21 including a single large concave curve surface extending from an inner peripheral portion 13 to a bent portion 17 of an outer peripheral portion 16.

[0066] However, the second embodiment differs from the reference example in that the blade 12 has outlet angles θ having the same features as those of the first embodiment shown in, for example, FIG. 3. Specifically, in the second embodiment, the blade 12 has a shape in which a peak outlet angle θ at the trailing edge 15 thereof exists in the outer region 12B of the blade 12 that is located radially outer than the representative square mean radius position R_r , and another peak outlet angle θ at the trailing edge 15 thereof exists in an inner region 12A of the blade 12 that is located radially inner than the representative square mean radius position R_r .

< Summary of Embodiments >

[0067] As described above, in the first embodiment and the second embodiment, the representative square mean radius position R_r serves as a reference at which the flow area of the propeller fan 4 is bisected into the radially inner region and the radially outer region, and each of the outer region 12B occupying one half of the flow area and the inner region 12A occupying the remaining half of the flow area is provided with the function of guiding air in the circumferential direction, thereby making it possible to effectively achieve the noise reduction.

[0068] Specifically, in these embodiments, the shape of the blade in which a peak outlet angle θ at the trailing edge 15 exists in the outer region 12B is adopted, to thereby obtain a large amount of work of the fan at the trailing edge 15 of the outer region 12B. This can enhance the effect of guiding air flowing along the pressure surface 21 of the outer region 12B in the circumferential direction. Further, in these embodiments, the shape of the blade

in which an another peak outlet angle θ at the trailing edge 15 exists in the inner region 12A is adopted, to thereby obtain a large amount of work of the fan also at the trailing edge 15 of in the inner region 12A. This can also enhance the effect of guiding air flowing along the pressure surface 21 of the inner region 12A in the circumferential direction. Therefore, it is possible to prevent air from flowing to the outer peripheral portion 16 (wing tip), and an increase in airflow (leakage flow) passing from the pressure surface 21 to the negative pressure surface 22 in the vicinity of the outer peripheral portion 16 is suppressed. Consequently, the occurrence of wing tip vortexes caused by leakage flow can be prevented, which makes it possible to achieve the noise reduction. Further, the prevention of an increase in leakage flow can also prevent degradation of blowing performance.

[0069] In the first embodiment, the inner region 12A includes the pressure surface 21 having a maximum radius of curvature greater than a maximum radius of curvature of the pressure surface 21 of the outer region 12B. In other words, in the first embodiment, the inner region 12A has a smaller maximum value of curvature radius and is therefore flatter than the outer region 12B. Therefore, the blade 12 is allowed to have a small cross-sectional area especially in the inner region 12A. This allows the blade 12 to be light in weight and small in volume.

[0070] In the first embodiment, the pressure surface 21 of the inner region 12A and the pressure surface 21 of the outer region 12B include a concave curve surface. In the first embodiment, because the pressure surface 21 of the inner region 12A and the pressure surface 21 of the outer region 12B each include a concave curve surface, it is possible to enhance, in each of the regions, the effect of guiding air flowing along the pressure surface 21 in the circumferential direction.

[0071] Furthermore, in the first embodiment, the pressure surface 21 of the outer region 12B has a maximum radius of curvature smaller than a maximum radius of curvature of the pressure surface 21 of the inner region 12A, and the respective pressure surfaces of the regions 12A and 12B each have a concave curve surface. Because changes in the pressure over the pressure surface 21 and the negative pressure surface 22 is great in the outer region 12B close to the outer peripheral portion 16, the radius of curvature in the outer region 12B is set to a small value, to thereby make it possible to enhance the effect of guiding air flowing along the pressure surface 21 of the outer region 12B in the circumferential direction. Consequently, the entire pressure surface 21 is further unlikely to cause the leakage flow.

[0072] In the first embodiment, the inner region 12A and the outer region 12B each have single concave curve surface and single peak outlet angle. Such relatively simple structure allows the blade 12 to be light in weight and small in volume while achieving the noise reduction.

[0073] In the first embodiment and the second embodiment, the trailing edge 15 of the blade 12 includes the recessed portion 19 in the region bearing the represent-

ative square mean radius position R_r , the recessed portion being oriented toward the leading edge 14. In these embodiments, the recessed portion 19 is provided in the region of the trailing edge 15 bearing the representative square mean radius position R_r where the pressure rise is otherwise liable to be greatest. Therefore, the pressure rise can be reduced in the vicinity of the recessed portion 19. This allows the air flowing from the leading edge 14 toward the trailing edge 15 to move toward the hub 11 and to the outer peripheral portion 16 in such a manner as to avoid the representative square mean radius position R_r in the vicinity of the trailing edge 15. This can enhance the effect of guiding airflow in the circumferential direction.

[0074] Further, in the blade 12 of the first embodiment, as clear from the positional relationship between an auxiliary line L1 and positions P1 and P2 shown in FIG. 2, the position P1 where the leading edge 14 and the outer peripheral portion 16 join each other is located further forward in the rotational direction D than the position P2 where the leading edge 14 and the inner peripheral portion 13 join each other.

[0075] Further, in the blade 12 of the first embodiment, as clear from the positional relationship between an auxiliary line L2 and positions P3 and P4 shown in FIG. 2, the position P3 where the trailing edge 15 and the outer peripheral portion 16 join each other is located further rearward in the rotational direction D than the position P4 where the trailing edge 15 and the inner peripheral portion 13 join each other.

[0076] In contrast, in the blade 112 of the propeller fan of the reference example shown in FIG. 4B, as clear from the positional relationship between an auxiliary line L12 and positions P13 and P14, the position P13 where the trailing edge 115 and the outer peripheral portion 116 join each other is located further forward in the rotational direction D than the position P14 where the trailing edge 115 and the inner peripheral portion 113 join each other.

[0077] Therefore, in the first embodiment shown in FIG. 2, the blade 12 is made to be compact especially in the inner region 12A and is thereby light in weight, compared to the reference example shown in FIG. 4B.

<Modifications>

[0078] Although the embodiments of the present invention have been described, the present invention is not limited to these embodiments. Various changes and modifications may be made without departing from the spirit of the invention.

[0079] The above-described embodiment illustrates the case where the propeller fan is used in the outdoor unit 1 of the air conditioner. However, the invention is not limited to this application. The propeller fan may be used, for example, as a fan for an indoor unit of an air conditioner or as a ventilation fan.

[0080] The first embodiment illustrates the case where the pressure surface 21 A of the inner region 12A and

the pressure surface 21B of the outer region 12B each have a concave curve surface. However, the invention is not limited to this configuration. For example, the pressure surface 21A of the inner region 12A may be in the form of a flat surface, while the pressure surface of the outer region 12B may be in the form of a curved surface (concave curve surface or convex curve surface). Alternatively, the pressure surface 21A of the inner region 12A may be in the form of a curved surface (concave curve surface or convex curve surface), while the pressure surface of the outer region 12B may be in the form of a flat surface.

[0081] The above-described embodiments are summarized as follows.

[0082] A propeller fan of the present invention includes a blade, and the blade has a shape in which a peak outlet angle at a trailing edge thereof exists in an outer region of the blade that is located radially outer than the representative square mean radius position, and another peak outlet angle at a trailing edge thereof exists in an inner region of the blade that is located radially inner than the representative square mean radius position.

[0083] In this configuration, the representative square mean radius position serves as a reference at which a flow area of the propeller fan is bisected into the radially inner region and the radially outer region, and each of the outer region occupying one half of the flow area and the inner region occupying the remaining half of the flow area is provided with a function of guiding air in a circumferential direction, thereby making it possible to effectively achieve noise reduction, specifically as follows.

[0084] Generally, air flowing along the pressure surface is liable to flow to the outer peripheral portion (wing tip) due to a pressure gradient, a centrifugal force and the like during rotation of the propeller fan.

[0085] Accordingly, in this configuration, the shape of the blade in which a peak outlet angle θ at the trailing edge exists in the outer region is adopted, to thereby obtain a large amount of work of the fan at the trailing edge of the outer region. This can enhance the effect of guiding air flowing along the pressure surface of the outer region in the circumferential direction. Further, in this configuration, the shape of the blade in which another peak outlet angle θ at the trailing edge exists in the inner region is adopted, to thereby obtain a large amount of work of the fan also at the trailing edge of the inner region. This can also enhance the effect of guiding air flowing along the pressure surface of the inner region in the circumferential direction. Therefore, it is possible to prevent air flowing to the outer peripheral portion (wing tip), and an increase in airflow (leakage flow) passing from the pressure surface to the negative pressure surface in the vicinity of the outer peripheral portion is suppressed. Consequently, the occurrence of wing tip vortexes caused by leakage flow can be prevented, which makes it possible to achieve noise reduction. Further, the prevention of an increase in leakage flow can also prevent degradation of blowing performance.

[0086] Further, as described above, in the propeller fan including the above-described configuration, air flowing onto the pressure surface of the blade from the leading edge is prevented from moving radially outward to the outer peripheral portion (wing tip), so that the air dominantly flows in the circumferential direction. This allows the hub to have a small height (thickness of the hub along the rotation axis A0), which allows the propeller fan to be light in weight, specifically as follows.

[0087] In the propeller fan, if the hub is made to have a small height, the blade will also need to have a small blade height in the inner peripheral portion thereof that joins the outer circumferential surface of the hub (at a joint where the blade joins the hub). The blade height refers to the difference in height (difference in height along the rotation axis) between one end (the leading edge end) and the other end (the trailing edge end) of a camber line on the joint. If the blade has a small height, the amount of work (head rise) of the blade is small in the vicinity of the joint, so that the air flowing onto the pressure surface from the leading edge is liable to move radially outward to the wing tip where the amount of work is large (the wing tip where the head rise is great). Therefore, if the hub is made to have a small height in the conventional propeller fan, it will be difficult to allow air to flow dominantly in the circumferential direction. In order to obtain a large amount of work (head rise) of the blade in the vicinity of the joint, it is appreciated to widen the blade extending in the form of a fan from the joint to the wing tip, in other words, lengthen a cord length in the vicinity of the joint, to thereby enlarge the area (increase the integrated value) of the pressure surface in the vicinity of the joint. However, this will increase the weight of the blade, which makes it difficult to provide a propeller fan that is light in weight.

[0088] On the other hand, in the propeller fan of the present invention, the blade having the shape in which a peak outlet angle at the trailing edge exists in the outer region and another peak outlet angle at the trailing edge exists in the inner region is adopted, which allows air to flow dominantly in the circumferential direction, as described above. Therefore, the propeller fan of the present invention is allowed to include the hub having a smaller height than the conventional fan and is thereby light in weight, while allowing air to flow dominantly in the circumferential direction.

[0089] In the propeller fan of the present invention, the peak outlet angle in the outer region and the peak outlet angle in the inner region may have the same or different values. In the case of having different values, the peak outlet angle in the outer region may have a greater or smaller value than the peak outlet angle in the inner region.

[0090] (2) In the propeller fan of the present invention, it is preferable that the inner region include a pressure surface having a maximum radius of curvature greater than a maximum radius of curvature of a pressure surface of the outer region.

[0091] In this configuration, because the inner region has a smaller maximum radius of curvature and is therefore flatter than the outer region, the blade is allowed to have a small cross-sectional area especially in the inner region. This allows the blade to be light in weight and small in volume.

[0092] in the propeller fan of the present invention, it is preferable that the pressure surface of the inner region and the pressure surface of the outer region each include a concave curve surface.

[0093] In this configuration, because the pressure surface of the inner region and the pressure surface of the outer region each include a concave curve surface, it is possible to enhance, in each of the regions, the effect of guiding air flowing along the pressure surface in the circumferential direction.

[0094] Furthermore, the following effect can be obtained by including both of the above-mentioned configurations (2) and (3). In this case, the pressure surface of the outer region has a maximum radius of curvature smaller than a maximum radius of curvature of the pressure surface of the inner region, and the respective pressure surfaces of the regions each have a concave curve surface. Because changes in the pressure over the pressure surface and the negative pressure surface is great in the outer region close to the outer peripheral portion, the radius of curvature in the outer region is set to a small value, to thereby make it possible to enhance the effect of guiding air flowing along the pressure surface of the outer region in the circumferential direction. Consequently, the entire pressure surface is further unlikely to cause the leakage flow.

[0095] (4) It is possible to provide, as an example, an embodiment of the propeller fan of the present invention wherein the inner region and the outer region each have single concave curve surface and single peak outlet angle.

[0096] (5) In the propeller fan of the present invention, it is preferable that the trailing edge of the blade have a recessed portion recessed toward a leading edge of the blade in a region including the representative square mean radius position.

[0097] In this configuration, the recessed portion is provided in the region of the trailing edge including the representative square mean radius position where the pressure rise is otherwise liable to be greatest. Therefore, the pressure rise can be reduced in the vicinity of the recessed portion. This allows the air flowing from the leading edge toward the trailing edge to move toward the hub and to the outer peripheral portion side in such a manner as to avoid the representative square mean radius position. This can enhance the effect of guiding airflow in the circumferential direction.

[0098] (6) An air conditioner of the present invention includes the above-mentioned propeller fan. Therefore, noise is reduced in this air conditioner.

Reference Signs List

[0099]

5	1	outdoor unit
	2	casing
	3	outdoor heat exchanger
	4	propeller fan
	5	motor
10	6	bell mouth
	7	discharge port
	8	axial flow blower
	11	hub
	12	blade
15	12A	inner region
	12B	outer region
	13	inner peripheral portion
	14	leading edge
	15	trailing edge
20	16	outer peripheral portion
	17	bent portion
	18	outer peripheral edge
	19	recessed portion
	19a	bottom
25	21	pressure surface
	21A	inner pressure surface
	21B	outer pressure surface
	22	negative pressure surface
	A0	rotation axis
30	D	rotational direction
	Rr	representative square mean radius position
	θ	outlet angle

35 Claims

1. A propeller fan comprising a blade, wherein the blade has a shape in which a peak outlet angle at a trailing edge thereof exists in an outer region of the blade that is located radially outer than the representative square mean radius position, and an another peak outlet angle at a trailing edge thereof exists in an inner region of the blade that is located radially inner than the representative square mean radius position.
2. A propeller fan according to claim 1, wherein the inner region includes a pressure surface having a maximum radius of curvature greater than a maximum radius of curvature of a pressure surface of the outer region.
3. A propeller fan according to claim 1 or 2, wherein the pressure surface of the inner region and the pressure surface of the outer region each include a concave curve surface.
4. A propeller fan according to any one of claims 1 to

3, wherein
the inner region and the outer region each have single concave curve surface and single peak outlet angle.

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5. A propeller fan according to any one of claims 1 to 4, wherein
the trailing edge of the blade has a recessed portion recessed toward a leading edge of the blade in a region including the representative square mean radius position.

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6. An air conditioner comprising a propeller fan according to any one of claims 1 to 5.

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FIG. 1

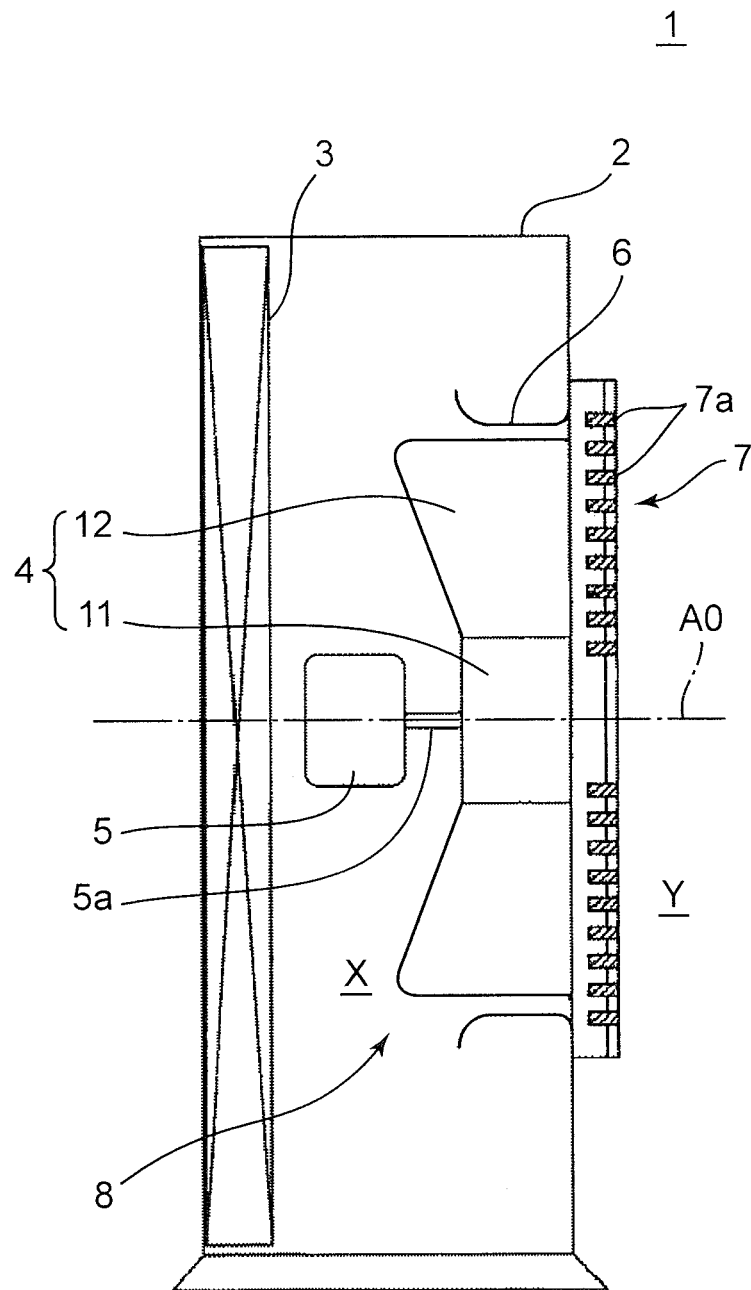


FIG. 2

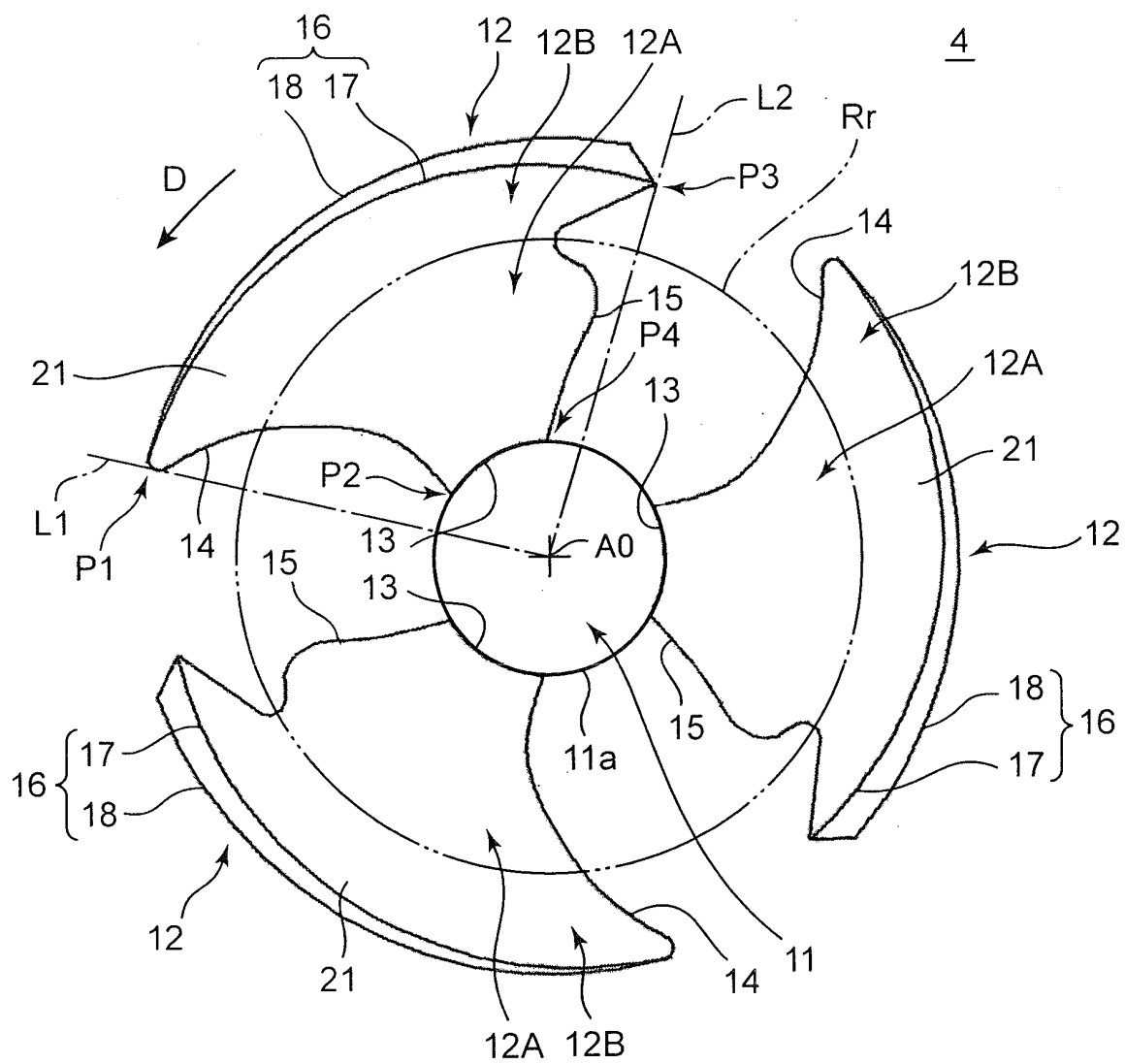


FIG. 3

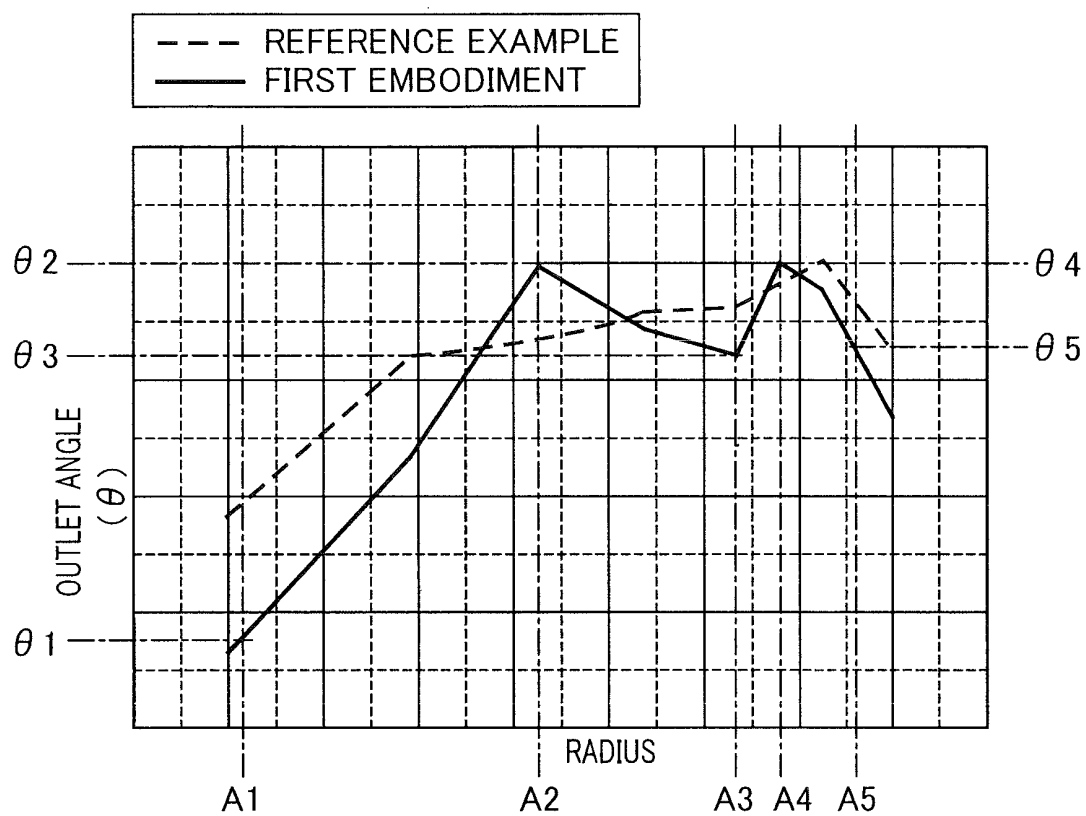


FIG. 4A

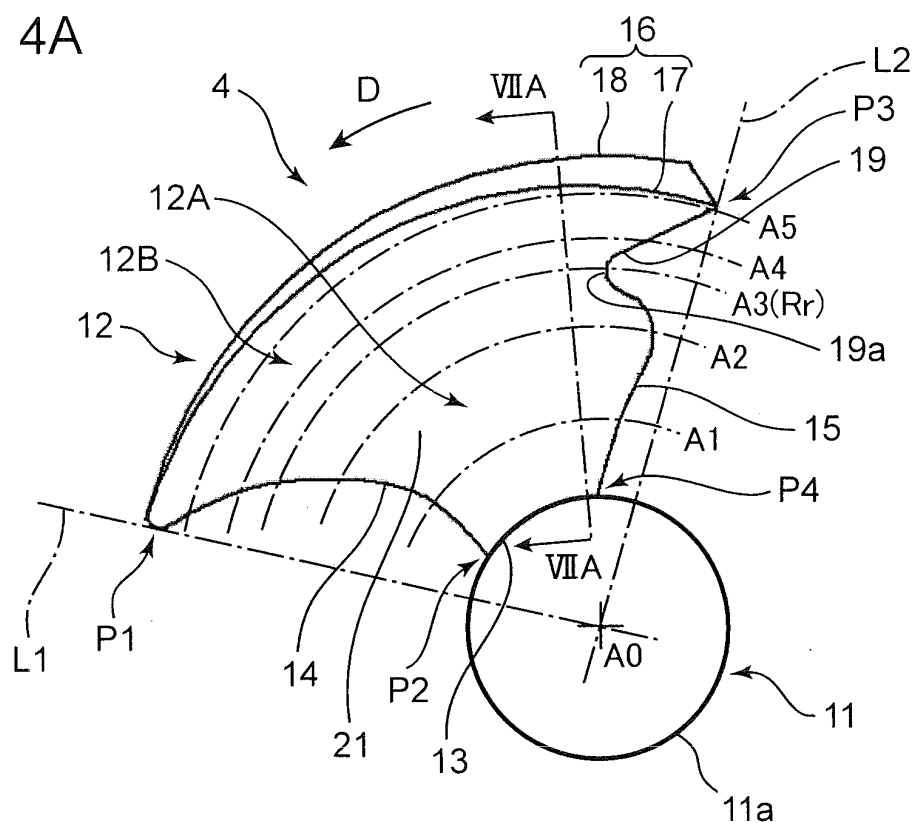


FIG. 4B

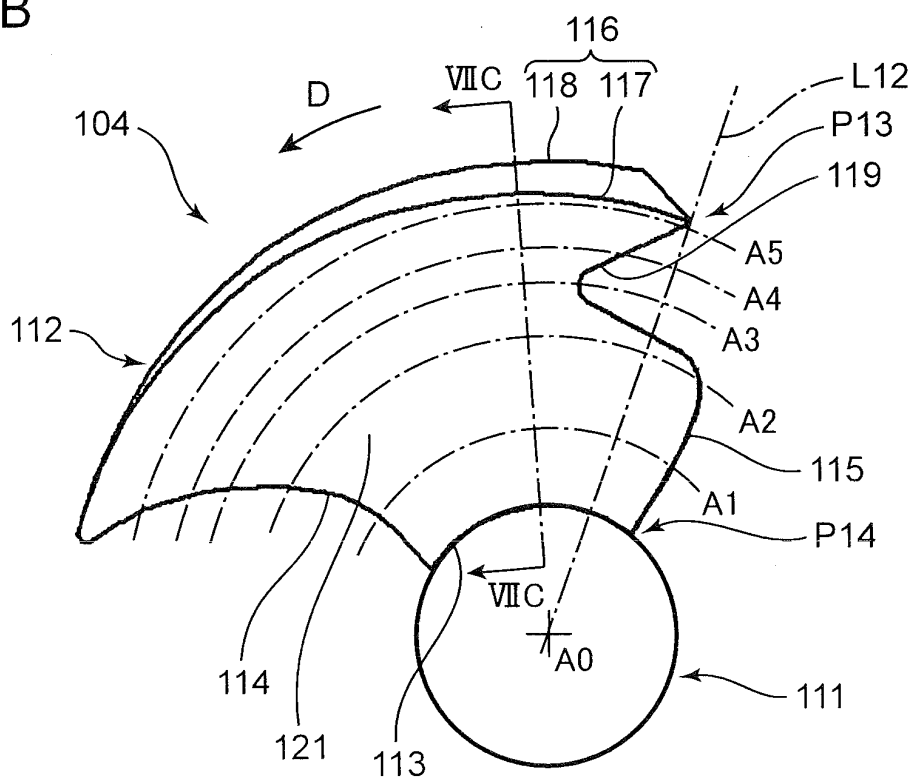


FIG. 5

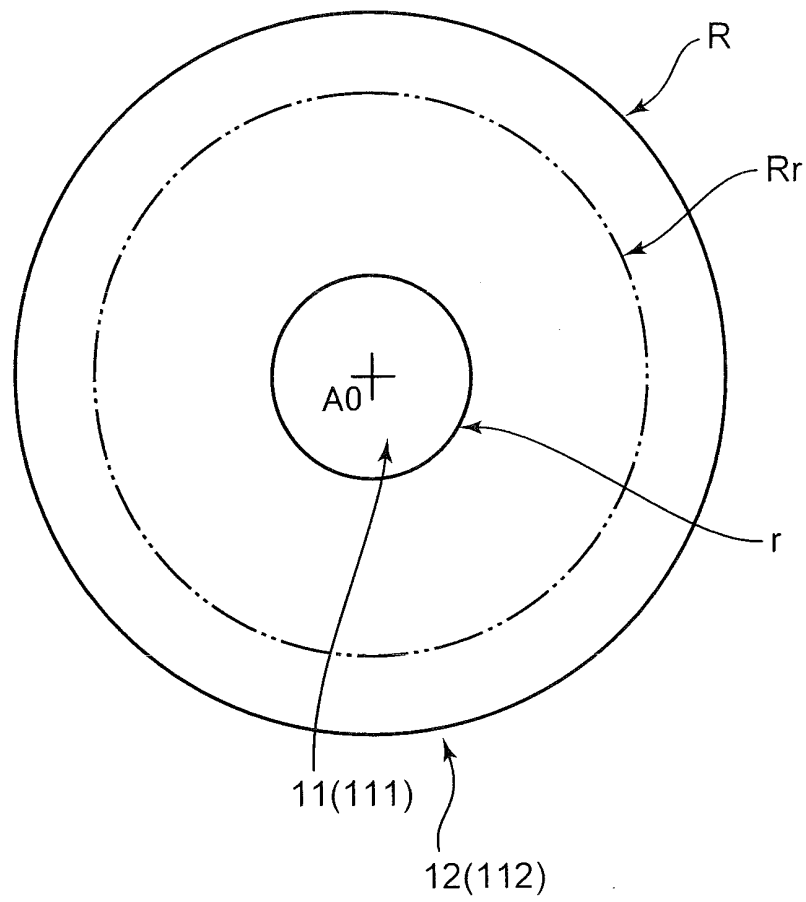


FIG. 6

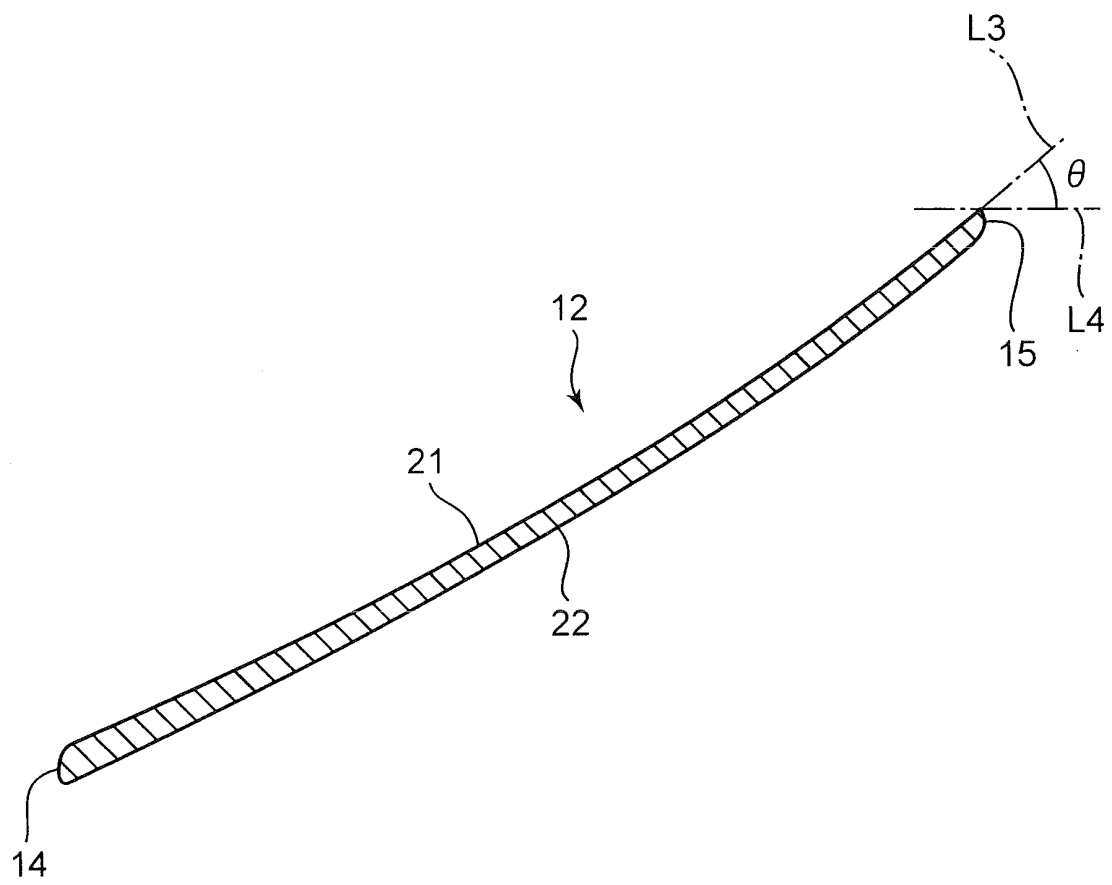


FIG. 7A

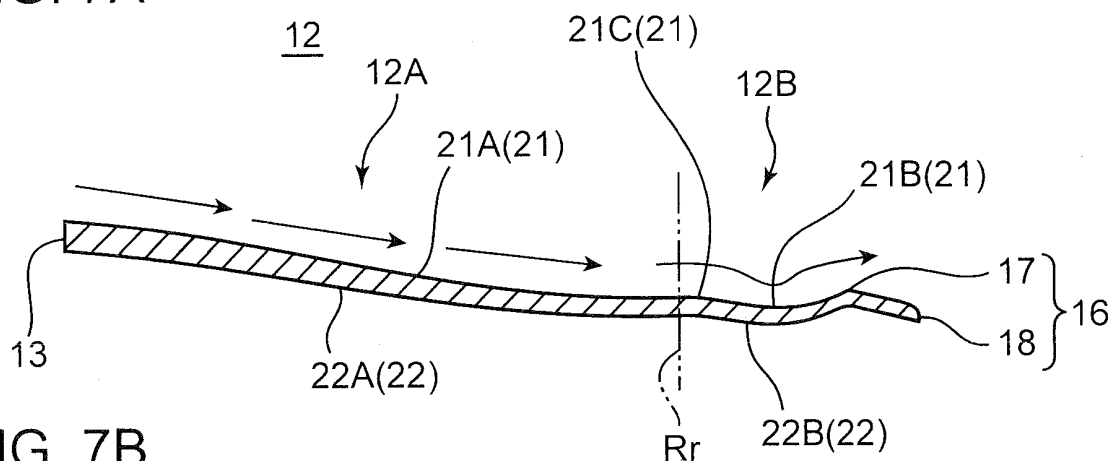


FIG. 7B

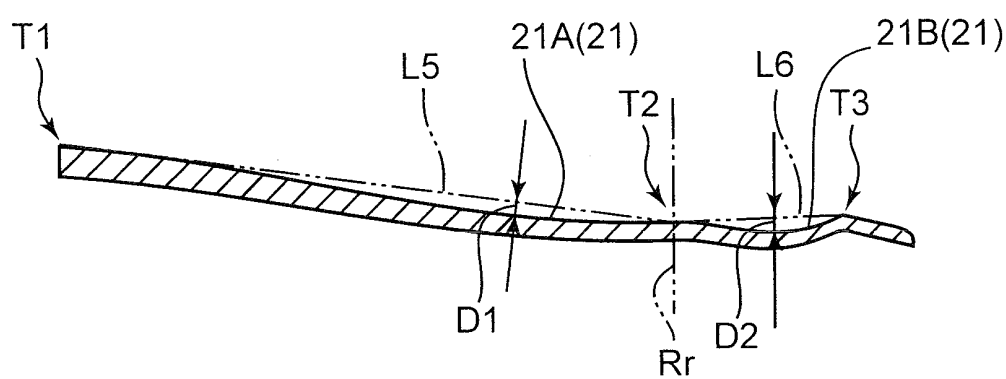


FIG. 7C

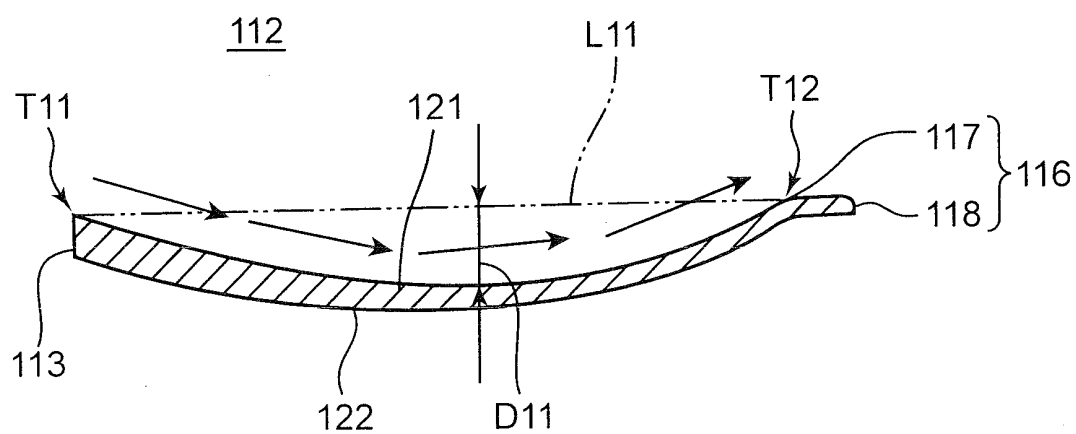


FIG. 8A

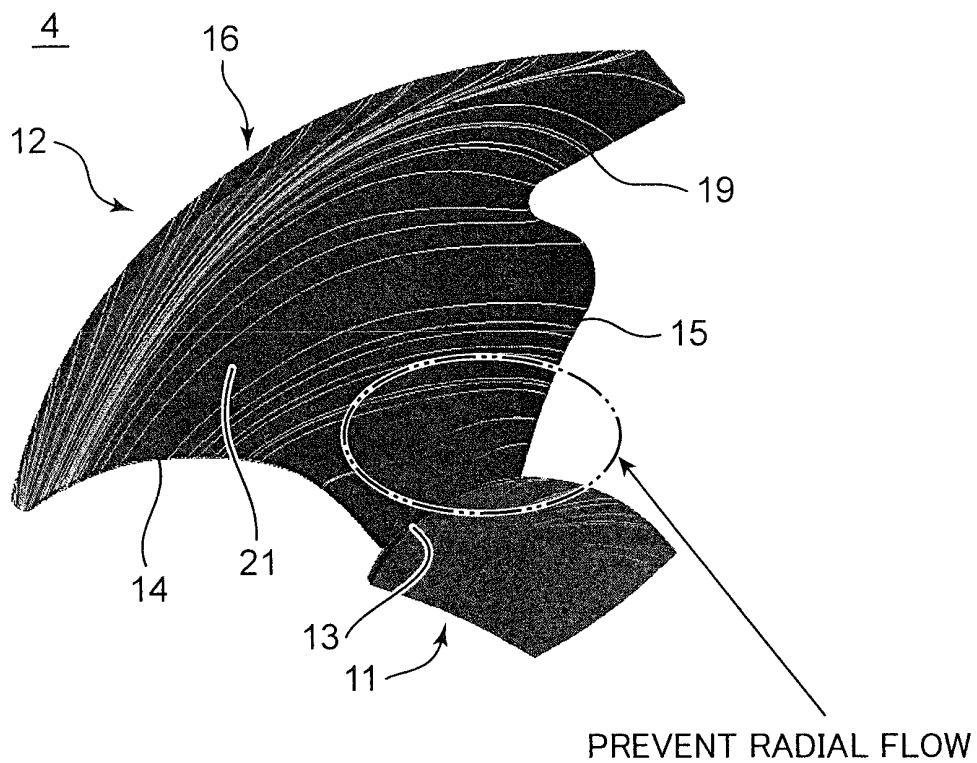


FIG. 8B

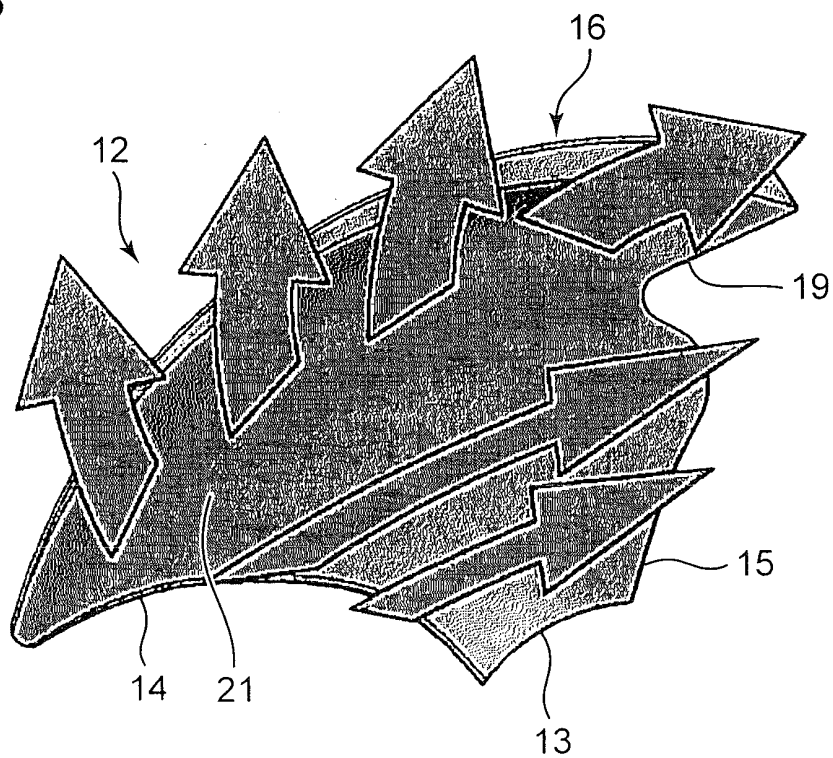


FIG. 10A

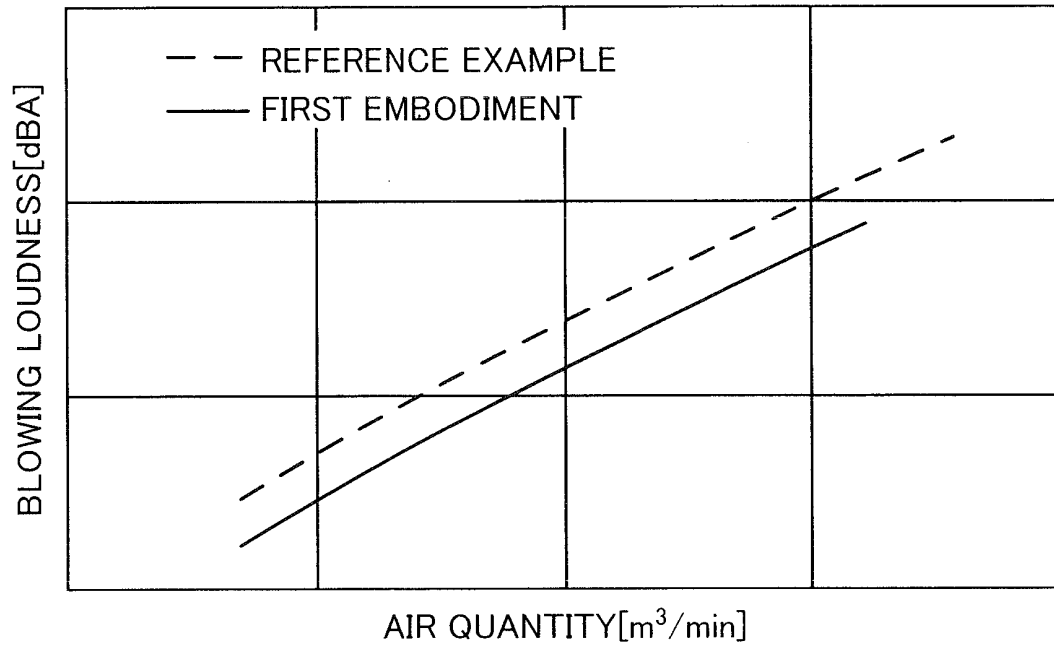


FIG. 10B

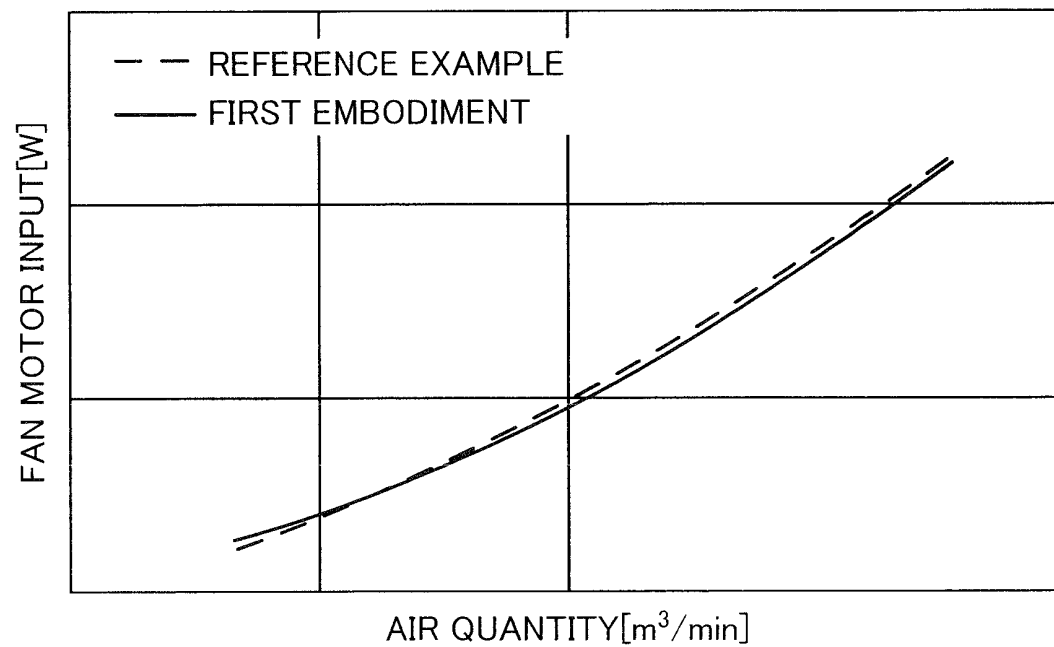


FIG. 11A

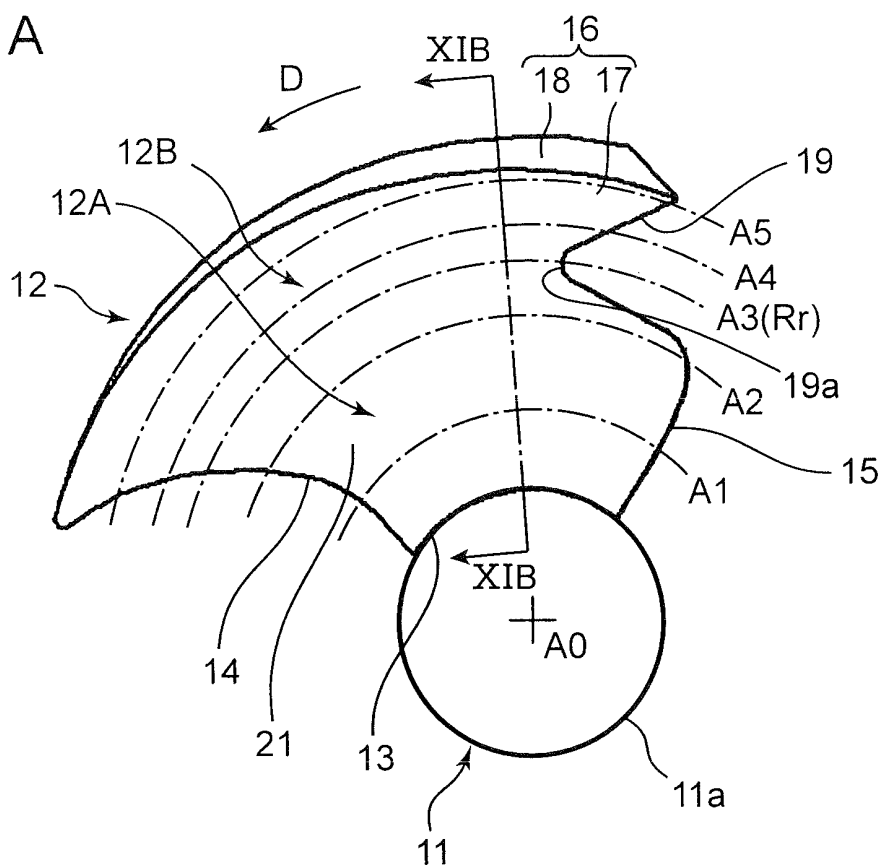
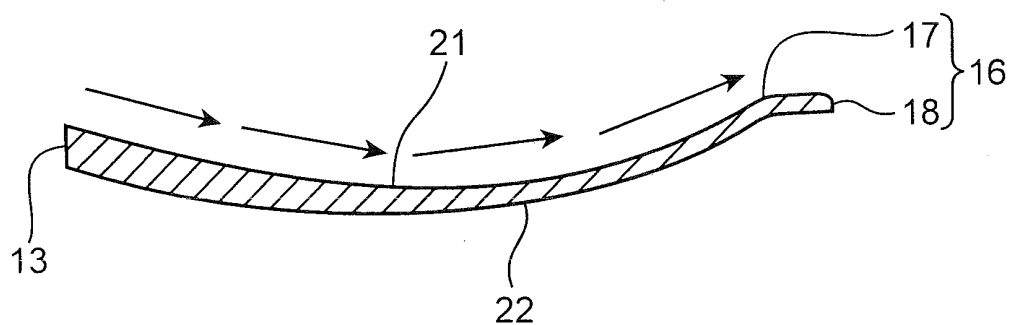


FIG. 11B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/005794

A. CLASSIFICATION OF SUBJECT MATTER

F04D29/38(2006.01)i, F04D29/66(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04D29/38, F04D29/66

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2006-37800 A (Mitsubishi Electric Corp.), 09 February 2006 (09.02.2006), entire text; all drawings & US 2008/0019826 A1 & EP 1783376 A1 & WO 2006/011333 A1	1, 3-4, 6 5-6 2
Y	JP 2003-206894 A (Sharp Corp.), 25 July 2003 (25.07.2003), entire text; all drawings (Family: none)	5-6
A	JP 2001-90693 A (Matsushita Electric Industrial Co., Ltd.), 03 April 2001 (03.04.2001), entire text; all drawings & EP 1087146 A2	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search
06 December, 2013 (06.12.13)Date of mailing of the international search report
17 December, 2013 (17.12.13)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/005794

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2001-73995 A (Daikin Industries, Ltd.), 21 March 2001 (21.03.2001), entire text; all drawings (Family: none)	1-6
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Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003072948 PCT [0005]