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(54) AXIAL FLOW FAN, BLOWING DEVICE, AND REFRIGERATION CYCLE DEVICE

(57) An axial fan includes a hub, and a blade. The hub has a rotation axis, and is configured to be driven to rotate. The blade is connected to the hub, and has a front edge and a rear edge. The blade has a flow control portion. The flow control portion is located in at least part of a portion between the front edge and the rear edge, and guides a flow of a fluid on a pressure surface of the blade. The flow control portion has a regional inner edge, a regional outer edge, and a sectional portion. The regional inner edge is located closer to the inner circumference of the axial fan than is the regional outer edge. The regional outer edge is located closer to the outer circumference of the axial fan than is the regional inner edge. The sectional portion is a section that is located between the regional inner edge and the regional outer edge and is perpendicular to the rotation axis. The sectional portion is bent to have a concave part of the pressure surface. In the flow control portion, a virtual regional intermediate line, which extends through the middle of a region between the regional inner edge and the regional outer edge in the radial direction, is located closer to the outer circumference than is a virtual blade intermediate line, which extends through the middle of the blade in the radial direction. In the sectional portion, the distance to a portion of the pressure surface that is farthest in the normal direction from a sectional straight line that is a straight line connecting the regional inner edge and the regional outer edge is defined as a projection amount. The projection amount increases with increasing distance from the front edge toward the rear edge.

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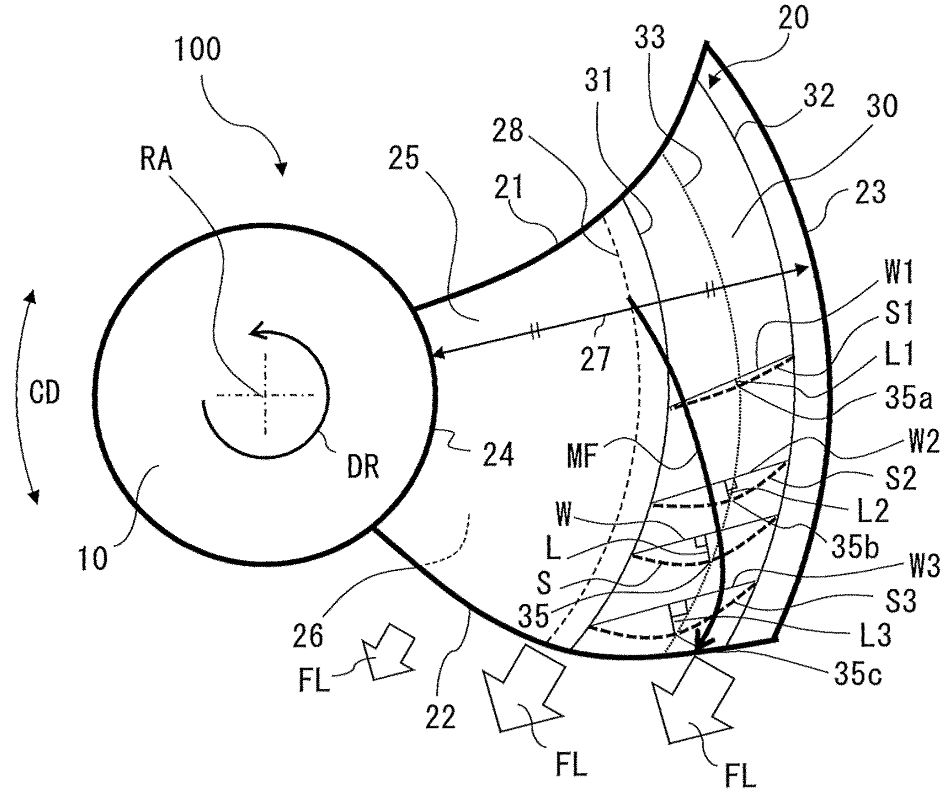
FIG. 3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Description

Technical Field

[0001] The present disclosure relates to an axial fan including multiple blades, an air-sending device including the axial fan, and a refrigeration cycle apparatus including the air-sending device.

Background Art

[0002] Some proposed axial fans in the related art include a cylindrical hub provided with multiple thin blades (see, for example, Patent Literature 1). In the axial fan disclosed in Patent Literature 1, each blade has a greater chord length near the outer circumference than near the hub. The axial fan disclosed in Patent Literature 1 is designed such that in a section of the blade taken in the radial direction, with reference to a point of curvature defined at a distance from the hub equal to approximately 1/3 of the length of the blade connecting a hub portion and an outer circumferential portion, the blade has a straight shape near the outer circumference, and a convex shape near the hub that is convex upstream in the direction of airflow.

[0003] According to the configuration of the axial fan disclosed in Patent Literature 1, the radial inflow of fluid through the outer circumference of the blade is facilitated by the straight portion located near the outer circumference and the convex portion located near the hub. This configuration is thus designed to optimize the natural flow of fluid around the blade. The above-mentioned configuration allows the axial fan disclosed in Patent Literature 1 to sufficiently exhibit fan characteristics of low-pressure propeller fans, that is, improved fan efficiency and reduced noise. This leads to reduced seasonal power consumption of air-conditioning apparatuses.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2011-236860

Summary of Invention

Technical Problem

[0005] Typically, for outdoor units used for air-conditioning apparatuses, designing the heat exchanger to operate at high pressure drop results in a strong fluid flow of a radial component directed toward the outer circumference of the blade. As described above, when viewed in section taken in the radial direction, the axial fan disclosed in Patent Literature 1 has a straight shape near the outer circumference. Accordingly, the presence of a strong fluid flow of a radial component directed toward the outer circumference of the blade may cause the fluid to leak at the outer circumferential end of the blade from the blade pressure surface toward the blade suction surface. This may result in formation of a strong blade tip vortex.

[0006] The present disclosure aims to address the above-mentioned problem. Accordingly, it is an object of the present disclosure to provide an axial fan that allows for reduced leakage of fluid from the blade pressure surface at the outer circumferential end of the blade to thereby reduce growth of a blade tip vortex, an air-sending device including the axial fan, and a refrigeration cycle apparatus including the air-sending device.

Solution to Problem

[0007] An axial fan according to an embodiment of the present disclosure includes a hub having a rotation axis and configured to be driven to rotate, and a blade connected to the hub and having a front edge and a rear edge. The blade has a flow control portion. The flow control portion is located in at least part of a portion between the front edge and the rear edge, and guides a flow of a fluid on a pressure surface of the blade. The flow control portion has a regional inner edge, a regional outer edge, and a sectional portion. The regional inner edge is located closer to the inner circumference of the axial fan than is the regional outer edge. The regional outer edge is located closer to the outer circumference of the axial fan than is the regional inner edge. The sectional portion is a section that is located between the regional inner edge and the regional outer edge and is perpendicular to the rotation axis. The sectional portion is bent to have a concave part of the pressure surface. In the flow control portion, a virtual regional intermediate line, which extends through the middle of a region between the regional inner edge and the regional outer edge in the radial direction, is located closer to the outer circumference than is a virtual blade intermediate line, which extends through the middle of the blade in the radial direction. In the sectional portion, the distance to a portion of the pressure surface that is farthest in the normal direction from a sectional straight line that is a straight line connecting the regional inner edge and the regional outer edge is defined as a projection amount. The projection amount increases with increasing distance from the front edge toward the rear edge.

[0008] An air-sending device according to an embodiment of the present disclosure includes the axial fan configured as described above, a drive source configured to provide a drive force to the axial fan, and a casing accommodating the axial fan and the drive source.

[0009] A refrigeration cycle apparatus according to an embodiment of the present disclosure includes the air-sending device configured as described above, and a refrigerant circuit having a condenser and an evaporator. The air-sending device is configured to send air to at least one of the condenser and the evaporator. Advantageous

Effects of Invention

[0010] According to an embodiment of the present disclosure, the virtual regional intermediate line, which extends through the middle of the region between the regional inner edge and the regional outer edge, is located closer to the outer circumference than is the virtual blade intermediate line, which extends through the middle of the blade in the radial direction. This allows the fluid flow to be guided toward an outer circumferential region of the blade where work is efficiently done on the fluid. Further, the axial fan is designed such that the projection amount of its sectional portion increases with increasing distance from the front edge toward the rear edge. This allows the fluid on the pressure surface to easily flow along the sectional portion, which causes the fluid flow on the pressure surface to concentrate in the sectional portion. The above-mentioned configuration of the axial fan therefore makes it possible to reduce leakage of the fluid from the blade pressure surface at the outer circumferential end of the blade, and consequently reduce growth of a blade tip vortex.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a schematic front view of an axial fan according to Embodiment 1.
[Fig. 2] Fig. 2 is a conceptual diagram representing a meridian plane of the axial fan according to Embodiment 1.
[Fig. 3] Fig. 3 is a schematic front view of a blade of the axial fan according to Embodiment 1.
[Fig. 4] Fig. 4 is a schematic front view of a blade of an axial fan according to a comparative example.
[Fig. 5] Fig. 5 is a schematic front view of a blade of an axial fan according to another comparative example.
[Fig. 6] Fig. 6 is a schematic front view of a blade of an axial fan according to Embodiment 2.
[Fig. 7] Fig. 7 is a schematic front view of a blade of an axial fan according to Embodiment 3.
[Fig. 8] Fig. 8 is a schematic front view of a blade of an axial fan according to Embodiment 4.
[Fig. 9] Fig. 9 is a schematic front view of a blade of an axial fan according to Embodiment 5.
[Fig. 10] Fig. 10 is another schematic front view of the blade of the axial fan according to Embodiment 5.
[Fig. 11] Fig. 11 is a conceptual diagram representing a meridian plane of an axial fan according to Embodiment 6.
[Fig. 12] Fig. 12 is a schematic front view of a blade of the axial fan according to Embodiment 6.
[Fig. 13] Fig. 13 is a schematic front view of a blade of an axial fan according to a modification of Embodiment 6.
[Fig. 14] Fig. 14 is a schematic front view of a blade of an axial fan according to Embodiment 7.
[Fig. 15] Fig. 15 is a conceptual diagram for explaining the configuration of an outdoor unit including the axial fan according to Embodiment 7.
[Fig. 16] Fig. 16 is a schematic front view of a blade of an axial fan according to Embodiment 8.
[Fig. 17] Fig. 17 is a schematic front view of a blade of an axial fan according to Embodiment 9.
[Fig. 18] Fig. 18 is a conceptual diagram, as viewed from top, of an outdoor unit including an axial fan according to Embodiment 10.
[Fig. 19] Fig. 19 is a conceptual diagram, as viewed from top, of an outdoor unit including an axial fan according to Embodiment 11.
[Fig. 20] Fig. 20 is a schematic diagram of a refrigeration cycle apparatus according to Embodiment 12.
[Fig. 21] Fig. 21 is a perspective view, as viewed from near an air outlet, of an outdoor unit serving as an air-sending device.
[Fig. 22] Fig. 22 is a top view of the outdoor unit for explaining the configuration of the outdoor unit.
[Fig. 23] Fig. 23 illustrates the outdoor unit with a fan grille removed from the outdoor unit.
[Fig. 24] Fig. 24 illustrates the internal configuration of the outdoor unit with the fan grille, a front panel, and other components removed from the outdoor unit. Description of Embodiments

[0012] An axial fan, an air-sending device, and a refrigeration cycle apparatus according to embodiments are described below with reference to the drawings. In the drawings below including Fig. 1, the relative dimensions, shapes, and other details of various components may differ from those of the actual components. In the drawings below, the same reference signs are used to indicate the same or corresponding elements or features throughout the specification. Although terms representing directions (e.g., "upper", "lower", "right", "left", "front", and "rear") are used as appropriate to facilitate understanding of the present disclosure, such terms are for illustrative purposes only and not intended to limit the corresponding apparatus, device, or component to any particular placement or orientation.

Embodiment 1.

[Axial Fan 100]

[0013] Fig. 1 is a schematic perspective view of an axial fan 100 according to Embodiment 1. A rotation direction DR shown by an arrow in Fig. 1 represents the direction of rotation of the axial fan 100. A circumferential direction CD shown by a double headed arrow in Fig. 1 represents the circumferential direction of the axial fan 100. The circumferential direction CD includes the rotation direction DR, and a direction opposite to the rotation direction DR. The far side of Fig. 1 corresponds to an upstream region upstream from the axial fan 100 in the direction of fluid flow, and the near side of Fig. 1 corresponds to a downstream region downstream from the axial fan 100 in the direction of fluid flow. The upstream region upstream from the axial fan 100 corresponds to a region where air is sucked into the axial fan 100, and the downstream region downstream from the axial fan 100 corresponds to a region where air is blown out from the axial fan 100.

[0014] The axial fan according to Embodiment 1 is described below with reference to Fig. 1. The axial fan 100 is a device for forming a flow of fluid. The axial fan 100 is used for, for example, an air-conditioning apparatus or a ventilator. The axial fan 100 forms a flow of fluid as the axial fan 100 rotates in the rotation direction DR about a rotation axis RA. An example of fluid is a gas such as air. As illustrated in Fig. 1, the axial fan 100 includes a hub 10 disposed along the rotation axis RA, and multiple blades 20 connected to the hub 10. Examples of the axial fan 100 include commonly-called boss-less fans having multiple blades 20, with the leading and trailing edge portions of adjacent blades 20 being connected to define a continuous surface with no boss between the leading and trailing edge portions.

(Hub 10)

[0015] The hub 10 is driven to rotate by a drive source such as a motor (not illustrated), and defines the rotation axis RA. The hub 10 rotates about the rotation axis RA. The rotation direction DR of the axial fan 100 is the counterclockwise direction shown by an arrow in Fig. 1. However, the rotation direction DR of the axial fan 100 may not necessarily be the counterclockwise direction. Alternatively, for example, the angle at which to mount the blades 20, or the orientation of the blades 20 may be changed such that the axial fan 100 rotates in the clockwise direction. The hub 10 is connected to the rotating shaft of a drive source such as a motor (not illustrated). In one example, the hub 10 may have a cylindrical shape, or may have a plate-like shape. The hub 10 is not limited to any particular shape as long as the hub 10 is connected to the rotating shaft of the drive source as mentioned above.

(Blades 20)

[0016] The blades 20 extend radially outward from the hub 10. The multiple blades 20 are arranged in radial formation such that the blades 20 extend radially outward from the hub 10. The multiple blades 20 are spaced apart from each other in the circumferential direction CD. Although Embodiment 1 is directed to an exemplary case where there are three blades 20, the number of blades 20 is not limited to three.

[0017] The blade 20 has a front edge 21, a rear edge 22, an outer circumferential edge 23, and an inner circumferential edge 24. The front edge 21 is located near the leading portion of the blade 20 in the rotation direction DR. That is, the front edge 21 is located forward of the rear edge 22 in the rotation direction DR. The front edge 21 is located upstream of the rear edge 22 in the direction of the fluid flow to be generated. The rear edge 22 is located near the trailing portion of the blade 20 in the rotation direction DR. That is, the rear edge 22 is located rearward of the front edge 21 in the rotation direction DR. The rear edge 22 is located downstream of the front edge 21 in the direction of the fluid flow to be generated. The axial fan 100 has the front edge 21 serving as a blade end oriented in the rotation direction DR of the axial fan 100, and the rear edge 22 serving as a blade end opposite to the front edge 21 in the rotation direction DR.

[0018] The outer circumferential edge 23 extends from the front to the rear of the blade 20 in the rotation direction DR such that the outer circumferential edge 23 connects the outermost circumferential portion of the front edge 21 with the outermost circumferential portion of the rear edge 22. The outer circumferential edge 23 has an arcuate shape when viewed parallel to the rotation axis RA. However, the outer circumferential edge 23 may not necessarily have an arcuate shape when viewed parallel to the rotation axis RA. The outer circumferential edge 23 is located at an end near the outer circumference of the axial fan 100 (to be also referred to simply as "outer circumference" hereinafter) in the radial direction (Y-axis direction).

[0019] The inner circumferential edge 24 extends from the front to the rear of the blade 20 in the rotation direction DR such that the inner circumferential edge 24 connects the innermost circumferential portion of the front edge 21 with the innermost circumferential portion of the rear edge 22. The inner circumferential edge 24 has an arcuate shape when viewed parallel to the rotation axis RA. However, the inner circumferential edge 24 may not necessarily have an arcuate shape when viewed parallel to the rotation axis RA. The inner circumferential edge 24 is located at an end near the inner circumference of the axial fan 100 (to be also referred to simply as "inner circumference" hereinafter) in the radial direction (Y-axis direction). The inner circumferential edge 24 of each blade 20 is connected to the hub 10, such as by being integrated with the hub 10.

[0020] The blades 20 are inclined toward a plane perpendicular to the rotation axis RA. As the axial fan 100 rotates, the blade surface of each blade 20 pushes the fluid present between the blades 20 to thereby transport the fluid. In this case, a blade surface that pushes the fluid and undergoes an increase in pressure is defined as a pressure surface 25, and a blade surface that is on the back of the pressure surface 25 and undergoes a decrease in pressure is defined as a suction surface 26. In the direction of fluid flow, the upstream surface of the blade 20 corresponds to the suction surface 26, and the downstream surface of the blade 20 corresponds to the pressure surface 25. A surface of the blade 20 depicted on the near side of Fig. 1 corresponds to the pressure surface 25, and a surface of the blade 20 depicted on the far side of Fig. 1 corresponds to the suction surface

26.

[0021] Fig. 2 is a conceptual diagram representing a meridian plane of the axial fan 100 according to Embodiment 1. Fig. 2 illustrates the shape of the axial fan 100 when rotated and projected onto a meridian plane that covers the rotation axis RA and the blades 20. For the axial fan 100, the shape of each blade 20 rotated and projected onto the meridian plane is represented by a blade projected portion 20p, and the shape of the hub 10 rotated and projected onto the meridian plane is represented by a hub projected portion 10p.

[0022] A front-edge projection line 21p represents the shape of the front edge 21 rotated about the rotation axis RA and projected onto the meridian plane that covers the rotation axis RA. A rear-edge projection line 22p represents the shape of the rear edge 22 rotated about the rotation axis RA and projected onto the meridian plane that covers the rotation axis RA. An outer-edge projection line 23p represents the shape of the outer circumferential edge 23 rotated about the rotation axis RA and projected onto the meridian plane that covers the rotation axis RA. An inner-edge projection line 24p represents the shape of the inner circumferential edge 24 rotated about the rotation axis RA and projected onto the meridian plane that covers the rotation axis RA.

[0023] A direction of flow AF shown by a vertically hatched arrow in Fig. 2 represents the direction of fluid flow into the axial fan 100. An axial direction AD shown by an open arrow in Fig. 2 represents the direction of the rotation axis RA. A viewpoint VP shown by a horizontally hatched arrow in Fig. 2 represents the direction of the line of sight taken parallel to the rotation axis RA. The Y-axis in Figs. 1 and 2 represents the radial direction from the rotation axis RA of the axial fan 100. Y2 represents a region of the axial fan 100 located closer to the inner circumference than is a region represented by Y1, and Y1 represents a region of the axial fan 100 located closer to the outer circumference that is the region represented by Y2.

[0024] Fig. 3 is a schematic front view of each blade 20 of the axial fan 100 according to Embodiment 1. To explain the configuration of each blade 20, Fig. 3 depicts only one of the multiple blades 20, and does not depict other blades 20. Airflows FL each shown by an open arrow in Fig. 3 each represent the flow of air downstream of the blade 20. The size of each open arrow showing the airflow FL conceptually represents airflow rate. The relative size of each open arrow showing the airflow FL represents relative airflow rate.

[0025] The blade 20 has a blade length 27, which represents the distance between the inner circumferential edge 24 and the outer circumferential edge 23, and a virtual blade intermediate line 28, which represents the radially middle part of the blade length 27. That is, the virtual blade intermediate line 28 represents a position in the middle of the distance between the inner circumferential edge 24 and the outer circumferential edge 23. The blade length 27 is the same at any position in the circumferential direction CD of the axial fan 100. That is, the blade length 27 of the blade 20 is constant in the region between the front edge 21 and the rear edge 22, and the outer circumferential edge 23 of the blade 20 has the shape of a circular arc when viewed parallel to the axial direction AD aligned with the rotation axis RA. However, the blade length 27 of the blade 20 may not necessarily be constant in the region between the front edge 21 and the rear edge 22. The blade length 27 of the blade 20 may vary with the position in the circumferential direction CD of the axial fan 100. That is, the outer circumferential edge 23 of the blade 20 may not necessarily have the shape of a circular arc when viewed parallel to the axial direction AD aligned with the rotation axis RA.

[0026] A position P1, a position P2, and a position P3 shown by dotted lines in Fig. 2 each represent the position of a section perpendicular to the rotation axis RA. In the axial direction AD aligned with the rotation axis RA, the position P1, the position P2, and the position P3 are in this order from an upstream region toward a downstream region in the direction of fluid flow. Portions of the axial fan 100 located in the plane of the section shown at the position P1 are located at the same position in the axial direction AD aligned with the rotation axis RA. Likewise, portions of the axial fan 100 located in the plane of the section shown at the position P2 are located at the same position in the axial direction AD aligned with the rotation axis RA. Likewise, portions of the axial fan 100 located in the plane of the section shown at the position P3 are located at the same position in the axial direction AD aligned with the rotation axis RA. As for the relationship between each portion of the axial fan 100 located in the plane of the section shown at the position P1, each portion of the axial fan 100 located in the plane of the section shown at the position P2, and each portion of the axial fan 100 located in the plane of the section shown at the position P3, these portions of the axial fan 100 are located at different positions in the axial direction AD aligned with the rotation axis RA. The position P1, the position P2, and the position P3 are representative of their relative locations between the front edge 21 and the rear edge 22. Although the foregoing description of Embodiment 1 is directed to the relationship between the three positions P1 to P3, such positional relationship is applicable not only to the three positions P1 to P3 but also to four or more positions.

(Flow Control Portion 30)

[0027] The blade 20 has a flow control portion 30. The flow control portion 30 is a portion of the blade 20 that guides the flow of fluid on the pressure surface 25. The flow control portion 30 is located in at least part of the portion between the front edge 21 and the rear edge 22, and has a constant width in the radial direction perpendicular to the rotation axis RA. The flow control portion 30 is a region having an arcuate shape when viewed parallel to the rotation axis RA. The flow control portion

30 has a regional inner edge 31, and a regional outer edge 32. The regional inner edge 31 is located closer to the inner circumference than is the regional outer edge 32. The regional outer edge 32 is located closer to the outer circumference than is the regional inner edge 31. The regional outer edge 32 is located closer to the outer circumference of the axial fan 100 than is the virtual blade intermediate line 28 in the radial direction. The regional inner edge 31 is located closer to the outer circumference of the axial fan 100 than is the virtual blade intermediate line 28 in the radial direction. It is to be noted, however, that the regional inner edge 31 may be located closer to the inner circumference of the axial fan 100 than is the virtual blade intermediate line 28 in the radial direction.

[0028] The regional inner edge 31 is formed in an arcuate shape, and located at a constant distance from the rotation axis RA in the radial direction of the axial fan 100. Likewise, the regional outer edge 32 is formed in an arcuate shape, and located at a constant distance from the rotation axis RA in the radial direction of the axial fan 100. The flow control portion 30 is a region located between the regional inner edge 31 and the regional outer edge 32. The flow control portion 30 is located in at least part of the portion between the front edge 21 and the rear edge 22 in the circumferential direction CD of the axial fan 100. That is, the flow control portion 30 extends in the blade 20 in the radial direction of the axial fan 100 and also in the circumferential direction CD.

[0029] The flow control portion 30 has a width in the radial direction that is constant at any position in the circumferential direction CD of the axial fan 100. That is, in the flow control portion 30, the distance between the regional inner edge 31 and the regional outer edge 32 in the radial direction is constant at any position in the circumferential direction CD of the axial fan 100. However, each of the regional inner edge 31 and the regional outer edge 32 may not necessarily be located at a constant distance from the rotation axis RA at any position in the radial direction of the axial fan 100. In this case, the axial fan 100 has a width in the radial direction that varies with the position in the circumferential direction CD of the axial fan 100.

[0030] The flow control portion 30 is located relatively close to the outer circumference in the radial direction of the blade 20. For example, the flow control portion 30 has a virtual regional intermediate line 33 that is located closer to the outer circumference than is the virtual blade intermediate line 28, which is located in the middle between the outer circumferential edge 23 and the inner circumferential edge 24. That is, the virtual regional intermediate line 33, which extends through the middle of the region between the regional inner edge 31 and the regional outer edge 32, is located closer to the outer circumference than is the virtual blade intermediate line 28, which extends through the middle of the blade 20 in the radial direction.

[0031] In the flow control portion 30, in at least part of a portion of the blade 20 between the front edge 21 and the rear edge 22 in the circumferential direction CD, the blade plate of the blade 20 is bent and cambered such that the section of the blade taken in the radial direction is convex in a direction opposite to the rotation direction DR of the axial fan 100. In the flow control portion 30, in at least part of the portion of the blade 20 between the front edge 21 and the rear edge 22 in the circumferential direction CD, the blade plate is bent and cambered to be convex upstream in the direction of the fluid flow to be created by the blade 20. That is, in at least part of the flow control portion 30 in the circumferential direction CD of the axial fan 100, the pressure surface 25 of the blade 20 is concave.

[0032] A sectional portion S shown by a dotted line in Fig. 3 represents a section of the blade 20 in the flow control portion 30. The sectional portion S represents a section of the flow control portion 30 perpendicular to the rotation axis RA. The flow control portion 30 has the sectional portion S, which is located between the regional inner edge 31 and the regional outer edge 32 and is a section perpendicular to the rotation axis RA. The sectional portion S is bent to have a concave part of the pressure surface 25, and a convex part of the suction surface 26. The sectional portion S is bent to be convex in a direction opposite to the rotation direction DR. Further, the sectional portion S is bent to be convex upstream in the direction of flow AF of the fluid. The sectional portion S is bent to have a concave part of the pressure surface 25, and a convex part of the suction surface 26. In the radial direction (Y-axis direction) of the axial fan 100, one end of the sectional portion S located near the inner circumference corresponds to the regional inner edge 31, and the other end of the sectional portion S located near the outer circumference corresponds to the regional outer edge 32. As for the shape of the sectional portion S of the blade 20, the suction surface 26 is not limited to a particular shape as long as the pressure surface 25 has a concave shape. In other words, as for the shape of the sectional portion S of the blade 20, the suction surface 26 is not limited to a particular shape as long as the pressure surface 25 is convex upstream in the direction of flow AF of the fluid to be created by the axial fan 100.

[0033] A sectional portion S1 shown by a dotted line in Fig. 3 represents the sectional portion S of the blade 20 in the flow control portion 30 at the position P1 illustrated in Fig. 2. A sectional portion S2 shown by a dotted line in Fig. 3 represents the sectional portion S of the blade 20 in the flow control portion 30 at the position P2 illustrated in Fig. 2. A sectional portion S3 shown by a dotted line in Fig. 3 represents the sectional portion S of the blade 20 in the flow control portion 30 at the position P3 illustrated in Fig. 2. More specifically, the sectional portion S1 represents a section of the flow control portion 30 that is taken at the position P1 in the axial direction AD and is perpendicular to the rotation axis RA. The sectional portion S2 represents a section of the flow control portion 30 that is taken at the position P2 in the axial direction AD and is perpendicular to the rotation axis RA.

The sectional portion S3 represents a section of the flow control portion 30 that is taken at the position P3 in the axial direction AD and is perpendicular to the rotation axis RA. In the radial direction (Y-axis direction) of the axial fan 100, one end of each of the sectional portions S1, S2, and S3 that is located near the inner circumference corresponds to the regional inner edge 31, and the other end of each of the sectional portions S1, S2, and S3 that is located near the outer circumference corresponds to the regional outer edge 32.

[0034] In the axial direction AD aligned with the rotation axis RA, the sectional portion S1, the sectional portion S2, and the sectional portion S3 of the flow control portion 30 are the sectional portions S that are positioned in this order from an upstream region toward a downstream region in the direction of fluid flow. In other words, in the circumferential direction CD of the axial fan 100, the sectional portion S1, the sectional portion S2, and the sectional portion S3 of the flow control portion 30 are the sectional portions S that are positioned in this order in a direction from the front edge 21 to the rear edge 22.

[0035] In the sectional portion S of the flow control portion 30, a straight line connecting the regional inner edge 31 and the regional outer edge 32 is defined as a sectional straight line W. In the sectional portion S, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the sectional straight line W connecting the regional inner edge 31 and the regional outer edge 32 is defined as a projection amount L. The projection amount L represents the distance in the normal direction from the sectional straight line W to a deepest part 35 of the sectional portion S where the blade 20 is most convex. The deepest part 35 is the most concave part of the pressure surface 25 in the sectional portion S of the flow control portion 30. That is, the deepest part 35 is a part where the sectional straight line W and the pressure surface 25 are farthest from each other in the sectional portion S of the flow control portion 30. In other words, the deepest part 35 is the most projecting part of the suction surface 26 in the sectional portion S of the flow control portion 30, and represents the vertex part of the convex shape defining the sectional portion S.

[0036] As with the above description of the sectional portion S, in the sectional portion S1 of the flow control portion 30 at the position P1, a straight line connecting the regional inner edge 31 and the regional outer edge 32 is defined as a sectional straight line W1. In the sectional portion S1, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the sectional straight line W1 connecting the regional inner edge 31 and the regional outer edge 32 is defined as a projection amount L1. The projection amount L1 is the distance in the normal direction from the sectional straight line W1 to a deepest part 35a of the sectional portion S1 where the blade 20 is most convex. The deepest part 35a is the most concave part of the pressure surface 25 in the sectional portion S1 of the flow control portion 30. That is, the deepest part 35a is a part where the sectional straight line W1 and the pressure surface 25 are farthest from each other in the sectional portion S1 of the flow control portion 30. In other words, the deepest part 35a is the most projecting part of the suction surface 26 in the sectional portion S1 of the flow control portion 30, and represents the vertex part of the convex shape defining the sectional portion S1.

[0037] As with the above description of the sectional portion S, in the sectional portion S2 of the flow control portion 30 at the position P2, a straight line connecting the regional inner edge 31 and the regional outer edge 32 is defined as a sectional straight line W2. In the sectional portion S2, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the sectional straight line W2 connecting the regional inner edge 31 and the regional outer edge 32 is defined as a projection amount L2. The projection amount L2 is the distance in the normal direction from the sectional straight line W2 to a deepest part 35b of the sectional portion S2 where the blade 20 is most convex. The deepest part 35b is the most concave part of the pressure surface 25 in the sectional portion S2 of the flow control portion 30. That is, the deepest part 35b is a part where the sectional straight line W2 and the pressure surface 25 are farthest from each other in the sectional portion S2 of the flow control portion 30. In other words, the deepest part 35b is the most projecting part of the suction surface 26 in the sectional portion S2 of the flow control portion 30, and represents the vertex part of the convex shape defining the sectional portion S2.

[0038] As with the above description of the sectional portion S, in the sectional portion S3 of the flow control portion 30 at the position P3, a straight line connecting the regional inner edge 31 and the regional outer edge 32 is defined as a sectional straight line W3. In the sectional portion S3, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the sectional straight line W3 connecting the regional inner edge 31 and the regional outer edge 32 is defined as a projection amount L3. The projection amount L3 is the distance in the normal direction from the sectional straight line W3 to a deepest part 35c of the sectional portion S3 where the blade 20 is most convex. The deepest part 35c is the most concave part of the pressure surface 25 in the sectional portion S3 of the flow control portion 30. That is, the deepest part 35c is a part where the sectional straight line W3 and the pressure surface 25 are farthest from each other in the sectional portion S3 of the flow control portion 30. In other words, the deepest part 35c is the most projecting part of the suction surface 26 in the sectional portion S3 of the flow control portion 30, and represents the vertex part of the convex shape defining the sectional portion S3.

[0039] The flow control portion 30 of the blade 20 is formed between the front edge 21 and the rear edge 22, and bent such that the projection amount L increases with increasing distance from the front edge 21 toward the rear edge 22. That is, the flow control portion 30 of the blade 20 is formed between the front edge 21 and the rear edge 22 such that bending of the blade 20 that is directed upstream increases with increasing distance from the front edge 21 toward the rear edge 22. In other words, the flow control portion 30 of the blade 20 is formed between the front edge 21 and the rear edge 22 such that the concave part of the pressure surface 25 increases in depth with increasing distance from the front edge 21 toward the rear edge 22. Therefore, in the flow control portion 30 of the blade 20, the projection amount L2 is greater than the projection amount L1, and the projection amount L3 is greater than the projection amount L2. The flow control portion 30 of the blade 20 is formed between the front edge 21 and the rear edge 22 such that the projection amounts L1, L2, and L3 satisfy the following relationship: L1 < L2 < L3. In this regard, the flow control portion 30 is formed in the same manner even when there are four or more sectional portions S. That is, in the circumferential direction CD, the projection amount L near the rear edge 22 is greater than the projection amount L near the front edge 21.

[Operation of Axial Fan 100]

[0040] As the axial fan 100 rotates in the rotation direction DR illustrated in Fig. 1, the pressure surface 25 of each blade 20 pushes out ambient air. As a result, the fluid flows in a direction orthogonal to the plane of Fig. 1. More specifically, rotation of the axial fan 100 in the rotation direction DR illustrated in Fig. 1 produces a fluid flow directed from the far side to the near side of Fig. 1. As the axial fan 100 rotates, the pressure on the suction surface 26 becomes lower than the pressure on the pressure surface 25. This causes a pressure difference to develop around each blade 20 between the pressure surface 25 and the suction surface 26.

[Advantageous Effects of Axial Fan 100]

[0041] In the axial fan 100, the virtual regional intermediate line 33, which extends through the middle of the region between the regional inner edge 31 and the regional outer edge 32, is located closer to the outer circumference than is the virtual blade intermediate line 28, which extends through the middle of the blade 20 in the radial direction. Further, in the axial fan 100, the projection amount L of the sectional portion S increases with increasing distance from the front edge 21 toward the rear edge 22. The above-mentioned configuration of the axial fan 100 allows the fluid on the pressure surface 25 to easily flow along the sectional portion S. This causes a fluid flow MF on the pressure surface 25 to concentrate in the sectional portion S. The above-mentioned configuration of the axial fan 100 therefore helps to prevent the fluid from being guided excessively toward the outer circumference of the blade 20. This makes it possible to reduce leakage of the fluid from the pressure surface 25 at the outer circumferential end of the blade 20, and consequently reduce growth of a blade tip vortex. A blade tip vortex refers to a vortex of air that is generated at the tip of the blade 20 because of a difference in pressure between the pressure surface 25 and the suction surface 26 of the blade 20. Generation of a blade tip vortex leads to unnecessary energy consumption. Accordingly, reducing generation of a blade tip vortex results in improved efficiency of the axial fan 100 and consequently reduced power consumption of the axial fan 100. Further, a blade tip vortex causes noise. Accordingly, reducing generation of a blade tip vortex helps to reduce noise associated with rotation of the blade 20.

[0042] With the flow control portion 30 viewed parallel to the rotation axis RA, the virtual regional intermediate line 33, which extends through the middle of the region between the regional inner edge 31 and the regional outer edge 32, is located closer to the outer circumference than is the virtual blade intermediate line 28, which extends through the middle of the blade 20 between the inner circumferential edge 24 and the outer circumferential edge 23. The axial fan 100 has the sectional portion S that is located near the outer circumference of the blade 20 and bent to have a concave part of the pressure surface 25. As a result, as represented by the fluid flow MF illustrated in Fig. 3, the fluid is guided from a region located closer to the inner circumference than is the sectional portion S, toward the sectional portion S located in an outer circumferential region where work is efficiently done on the fluid. As illustrated in Fig. 3, the airflow FL is greater in an outer circumferential region of the blade 20 where work is efficiently done on the fluid, than in an inner circumferential region of the blade 20. Accordingly, the axial fan 100 configured as described above efficiently does work on the fluid in comparison with axial fans in which a comparatively more fluid flows near the inner circumference of the blade 20. This leads to reduced power consumption of the axial fan 100.

[0043] Fig. 4 is a schematic front view of a blade 20L of an axial fan 100L according to a comparative example. A flow control portion 30L of the blade 20L has a sectional portion SL. The sectional portion SL represents a section of the flow control portion 30L perpendicular to the rotation axis RA. A sectional portion SL1 corresponds to the sectional portion SL at the position P1 illustrated in Fig. 2. A sectional portion SL2 corresponds to the sectional portion SL at the position P2 illustrated in Fig. 2. A sectional portion SL3 corresponds to the sectional portion SL at the position P3 illustrated in Fig. 2. In the axial fan 100L according to the comparative example, the sectional portion SL located near the outer circumference of the blade has a straight shape rather than a bent shape. As the sectional portion SL located near the outer circumference of the blade has a straight shape rather than a bent shape as described above, the axial fan 100L does not draw, toward the inner circumference of the blade, a fluid flow directed toward the outer circumference of the blade. This may result in a leakage fluid flow at the outer circumferential end of the blade 20L.

[0044] In the axial fan 100L, the fluid flow on the pressure surface 25 moves in the radial direction of the blade 20 with the radial component gradually increasing with increasing distance from an upstream region toward a downstream region in the direction of fluid flow. Accordingly, as with the axial fan 100 according to Embodiment 1, shaping the blade 20 to have the sectional portion S helps to prevent the fluid from being guided excessively toward the outer circumference of the blade 20 in the axial fan 100 according to Embodiment 1. Further, in the axial fan 100, the fluid flow concentrates in the sectional portion S of the blade 20. Therefore, the above-mentioned configuration makes it possible to reduce leakage of the fluid from the pressure surface 25 at the outer circumferential end of the blade 20, and consequently reduce growth of a blade tip vortex.

[0045] The blade 20L of the axial fan 100L employs a configuration described below to reduce generation of a blade tip vortex. That is, the sectional portion SL is not formed in a convex shape, and is oriented to draw the flow of fluid toward the inner circumferential edge 24, with no changes in concavity and convexity from the front edge 21 to the rear edge 22. The above-mentioned configuration may make it possible for the axial fan 100L to draw the flow of fluid toward the inner circumferential edge 24 to thereby reduce the leakage of fluid at the outer circumferential end of the blade 20. The above-mentioned configuration of the axial fan 100L, however, fails to increase the load on an outer circumferential region of the blade 20 where work is efficiently done on the fluid, and consequently fails to sufficiently reduce the power consumption of the axial fan 100.

[0046] As described above, the axial fan 100L draws the fluid toward the inner circumferential edge 24. This causes a maximum air velocity region MA to develop on the pressure surface 25 where the fluid flow concentrates. As illustrated in Fig. 4, the airflow FL concentrating in and then exiting from the maximum air velocity region MA is greater than the airflow FL near the inner circumferential edge 24 of the blade 20 and the airflow FL near the outer circumferential edge 23 of the blade 20. This results in increased energy loss of the axial fan 100L because of collision of the airflow with a structure such as a grill located downstream of the maximum air velocity region MA. This may lead to increased noise, and increased power consumption of the axial fan 100L.

[0047] By contrast, the axial fan 100 according to Embodiment 1 allows for increased air velocity in the sectional portion S located near the outer circumference in the radial direction. This helps to ensure that in the axial fan 100 according to Embodiment 1, the velocity distribution of the fluid blown by the axial fan 100 is made uniform in a region of the axial fan 100 located closer to the outer circumference than is the maximum air velocity region ML in the radial direction. Therefore, the axial fan 100 according to Embodiment 1 makes it possible to reduce energy loss resulting from the collision of the fluid with a structure such as a grill located downstream of the axial fan 100. The axial fan 100 according to Embodiment 1 also makes it possible to reduce noise resulting from the collision of the fluid with a structure such as a grill located downstream of the axial fan 100, and reduce the required power consumption of the axial fan 100.

[0048] Fig. 5 is a schematic front view of a blade 20R of an axial fan 100R according to another comparative example. A flow control portion 30R of the blade 20R has a sectional portion SR. The sectional portion SR represents a section of the flow control portion 30R perpendicular to the rotation axis RA. A sectional portion SR1 corresponds to the sectional portion SR at the position P1 illustrated in Fig. 2. A sectional portion SR2 corresponds to the sectional portion SR at the position P2 illustrated in Fig. 2. A sectional portion SR3 corresponds to the sectional portion SR at the position P3 illustrated in Fig. 2.

[0049] The sectional portion SR of the axial fan 100R according to the comparative example is bent such that the sectional portion SR is convex in a direction opposite to the rotation direction DR. The sectional portion SR is bent to have a concave part of the pressure surface 25, and a convex part of the suction surface 26. It is to be noted, however, that in the axial fan 100R according to the comparative example, the sectional portion SR1, the sectional portion SR2, and the sectional portion SR3 have the same shape from the front edge 21 to the rear edge 22. That is, the flow control portion 30R of the blade 20R is formed between the front edge 21 and the rear edge 22 such that the projection amounts L1, L2, and L3 satisfy the following relationship: L1 = L2 = L3.

[0050] The flow control portion 30R of the blade 20R has the sectional portion SR, and is formed between the front edge 21 and the rear edge 22 such that the projection amounts L1, L2, and L3 satisfy the following relationship: L1 = L2 = L3. The axial fan 100R according to the comparative example has the sectional portion SR that is convex from a downstream region toward an upstream region in the direction of fluid flow. Because of the above-mentioned shape of the sectional portion SR, the fluid is guided from a region located closer to the inner circumference than is the sectional portion SR, toward the sectional portion S located in an outer circumferential region where work is efficiently done on the fluid. This makes it possible to increase the load in the outer circumferential region where work is efficiently done on the fluid.

[0051] However, the axial fan 100R has the projection amount L that is constant from the front edge 21 to the rear edge 22. This results in a fluid flow MB being guided excessively toward the outer circumference. As illustrated in Fig. 5, with increasing distance from the inner circumferential edge 24 of the blade 20 toward the outer circumferential edge 23, the airflow FL near the outer circumferential edge 23 of the blade 20 increases in comparison with the airflow FL near the inner circumferential edge 24 of the blade 20. Consequently, leakage of the fluid flow MB occurs at the outermost circumference of the blade 20 of the axial fan 100R. The resulting growth of a blade tip vortex may result in increased noise, or may result in increased power consumption of the axial fan 100R.

[0052] By contrast, in the sectional portion S of the axial fan 100 according to Embodiment 1, the projection amount L of the sectional portion S increases with increasing distance from the front edge 21 toward the rear edge 22 in the direction of fluid flow. This allows the fluid on the pressure surface 25 to easily flow along the sectional portion S, which causes the fluid flow on the pressure surface 25 to concentrate in the sectional portion S. The above-mentioned configuration of the axial fan 100 according to Embodiment 1 helps to reduce leakage of the fluid from the pressure surface 25 at the outer circumferential end of the blade 20, and consequently reduce growth of a blade tip vortex.

Embodiment 2.

[Axial Fan 100A]

[0053] Fig. 6 is a schematic front view of a blade 20A of an axial fan 100A according to Embodiment 2. Reference is made below to Fig. 6 to describe the configuration of the blade 20A in detail. Portions or parts of the axial fan 100A identical in configuration to those of the axial fan 100 illustrated in Figs. 1 to 3 are denoted by the same reference signs and not described below in further detail. For the axial fan 100A according to Embodiment 2, the location of the deepest part 35 of a flow control portion 30A is specified.

[0054] As described above, the deepest part 35 is the most concave part of the pressure surface 25 in the sectional portion S of the flow control portion 30. Further, the deepest part 35 is the most projecting part of the suction surface 26 in the sectional portion S of the flow control portion 30, and represents the vertex part of the convex shape defining the sectional portion S. The deepest part 35a corresponds to the deepest part 35 of the sectional portion S1 in the flow control portion 30A. The deepest part 35b corresponds to the deepest part 35 of the sectional portion S2 in the flow control portion 30A. The deepest part 35c corresponds to the deepest part 35 of the sectional portion S3 in the flow control portion 30A. In the circumferential direction CD of the axial fan 100A, the sectional portion S1, the sectional portion S2, and the sectional portion S3 of the flow control portion 30A are the sectional portions S that are positioned in this order in a direction from the front edge 21 to the rear edge 22.

[0055] A distance R1 in Fig. 6 is the distance between the rotation axis RA and the deepest part 35a in the radial direction of the axial fan 100A. Likewise, a distance R2 is the distance between the rotation axis RA and the deepest part 35b in the radial direction of the axial fan 100A. Likewise, a distance R3 is the distance between the rotation axis RA and the deepest part 35c in the radial direction of the axial fan 100A. In the flow control portion 30A of the axial fan 100A, the distance R2 is greater than the distance R1, and the distance R3 is greater than the distance R2. That is, in the axial fan 100A, the distances R1, R2, and R3 have the following relationship: $R1 < R2 < R3$. In the flow control portion 30A of the axial fan 100A, the deepest part 35 is located at a distance from the rotation axis RA in the radial direction that increases with increasing distance from the front edge 21 toward the rear edge 22 in the circumferential direction. In the flow control portion 30A, with increasing distance from the front edge 21 toward the rear edge 22 in the circumferential direction, the deepest part 35 is positioned further toward the outer circumferential edge 23 of the blade 20A from a location near the inner circumference in the radial direction.

[Advantageous Effects of Axial Fan 100A]

[0056] In the flow control portion 30A of the axial fan 100, the deepest part 35 is positioned further toward the outer circumference in the radial direction with increasing distance from the front edge 21 toward the rear edge 22 in the circumferential direction. The fluid flow along the pressure surface 25 of the blade 20A caused by rotation of the axial fan 100 concentrates most at the deepest part 35 of the sectional portion S on the pressure surface 25 of the blade 20A. Accordingly, because of the above-mentioned configuration of the axial fan 100A in which the deepest part 35 is positioned further toward the outer circumference in the radial direction with increasing distance from the front edge 21 toward the rear edge 22, more fluid flow is guided toward an outer circumferential region where work is efficiently done on the fluid. As a result, the axial fan 100A directs more fluid toward the outer circumferential region of the blade 20A where work is efficiently done on the fluid. This makes it possible to reduce the required power consumption of the axial fan 100A. Further, the above-mentioned configuration allows for improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 100A. This leads to reduced noise generation.

Embodiment 3.

[Axial Fan 100B]

[0057] Fig. 7 is a schematic front view of a blade 20B of an axial fan 100B according to Embodiment 3. Reference is made below to Fig. 7 to describe the configuration of the blade 20B in detail. Portions or parts of the axial fan 100B identical in configuration to those of the axial fans 100 and 100A illustrated in Figs. 1 to 6 are denoted by the same reference signs and not described below in further detail. For the axial fan 100B according to Embodiment 3, the orientation of the sectional portion S of a flow control portion 30B is specified.

[0058] The sectional straight line W1 corresponds to the sectional straight line W connecting the regional inner edge 31 and the regional outer edge 32 in the sectional portion S1 of the flow control portion 30B at the position P1 illustrated in Fig. 2. In this case, the intersection of the sectional straight line W1 and the regional inner edge 31 is defined as an inner-circumference-side end W1a, and the intersection of the sectional straight line W1 and the regional outer edge 32 is defined as an outer-circumference-side end W1b. The inner-circumference-side end W1a is an end of the sectional straight line W1 located near the inner circumference in the radial direction. The outer-circumference-side end W1b is an end of the sectional straight line W1 located near the outer circumference in the radial direction. In the circumferential direction, the outer-circumference-side end W1b is located closer to the front edge 21 than is the inner-circumference-side end W1a, and the inner-circumference-side end W1a is located closer to the rear edge 22 than is the outer-circumference-side end W1b. That is, in the flow control portion 30B, the outer-circumference-side end W1b is located closer to the leading portion of the axial fan 100B in the rotation direction DR than is the inner-circumference-side end W1a.

[0059] A straight line passing the rotation axis RA and the inner-circumference-side end W1a is defined as a straight line M1a, and a straight line passing the rotation axis RA and the outer-circumference-side end W1b is defined as a straight line M1b. The angle between the straight line M1a and the straight line M1b in the circumferential direction is defined as an angle θ1. The angle θ1 is an angle defined between the two straight lines, that is, the straight line M1a connecting the rotation axis RA, which is at the center of the axial fan 100B, with the inner-circumference-side end W1a of the sectional portion S1 of the flow control portion 30B, and the straight line M1b connecting the rotation axis RA with the outer-circumference-side end W1b of the sectional portion S1 of the flow control portion 30B.

[0060] Likewise, the sectional straight line W2 corresponds to the sectional straight line W connecting the regional inner edge 31 and the regional outer edge 32 in the sectional portion S2 of the flow control portion 30B at the position P2 illustrated in Fig. 2. In this case, the intersection of the sectional straight line W2 and the regional inner edge 31 is defined as an inner-circumference-side end W2a, and the intersection of the sectional straight line W2 and the regional outer edge 32 is defined as an outer-circumference-side end W2b. The inner-circumference-side end W2a is an end of the sectional straight line W2 located near the inner circumference in the radial direction. The outer-circumference-side end W2b is an end of the sectional straight line W2 located near the outer circumference in the radial direction. In the circumferential direction, the outer-circumference-side end W2b is located closer to the front edge 21 than is the inner-circumference-side end W2a, and the inner-circumference-side end W2a is located closer to the rear edge 22 than is the outer-circumference-side end W2b. That is, in the flow control portion 30B, the outer-circumference-side end W2b is located closer to the leading portion of the axial fan 100B in the rotation direction DR than is the inner-circumference-side end W2a.

[0061] A straight line passing the rotation axis RA and the inner-circumference-side end W2a is defined as a straight line M2a, and a straight line passing the rotation axis RA and the outer-circumference-side end W2b is defined as a straight line M2b. The angle between the straight line M2a and the straight line M2b in the circumferential direction is defined as an angle θ2. The angle θ2 is an angle defined between the two straight lines, that is, the straight line M2a connecting the rotation axis RA, which is at the center of the axial fan 100B, with the inner-circumference-side end W2a of the sectional portion S2 of the flow control portion 30B, and the straight line M2b connecting the rotation axis RA with the outer-circumference-side end W2b of the sectional portion S2 of the flow control portion 30B.

[0062] Likewise, the sectional straight line W3 corresponds to the sectional straight line W connecting the regional inner edge 31 and the regional outer edge 32 in the sectional portion S3 of the flow control portion 30B at the position P3 illustrated in Fig. 2. In this case, the intersection of the sectional straight line W3 and the regional inner edge 31 is defined as an inner-circumference-side end W3a, and the intersection of the sectional straight line W3 and the regional outer edge 32 is defined as an outer-circumference-side end W3b. The inner-circumference-side end W3a is an end of the sectional straight line W3 located near the inner circumference in the radial direction. The outer-circumference-side end W3b is an end of the sectional straight line W3 located near the outer circumference in the radial direction. In the circumferential direction, the outer-circumference-side end W3b is located closer to the front edge 21 than is the inner-circumference-side end W3a, and the inner-circumference-side end W3a is located closer to the rear edge 22 than is the outer-circumference-side end W3b. That is, in the flow control portion 30B, the outer-circumference-side end W3b is located closer to the leading portion of the axial fan 100B in the rotation direction DR than is the inner-circumference-side end W3a.

[0063] A straight line passing the rotation axis RA and the inner-circumference-side end W3a is defined as a straight line M3a, and a straight line passing the rotation axis RA and the outer-circumference-side end W3b is defined as a straight line M3b. The angle between the straight line M3a and the straight line M3b in the circumferential direction is defined as an angle θ3. The angle θ3 is an angle defined between the two straight lines, that is, the straight line M3a connecting the rotation axis RA, which is at the center of the axial fan 100B, with the inner-circumference-side end W3a of the sectional portion S3 of the flow control portion 30B, and the straight line M3b connecting the rotation axis RA with the outer-circumference-side end W3b of the sectional portion S3 of the flow control portion 30B.

[0064] The inner-circumference-side end W1a, the inner-circumference-side end W2a, and the inner-circumference-side end W3a each correspond to a first inner-circumference-side end, and the outer-circumference-side end W1b, the outer-circumference-side end W2b, and the outer-circumference-side end W3b each correspond to a first outer-circumference-side end. The straight line M1a, the straight line M2a, and the straight line M3a each correspond to a first straight line, and the straight line M1b, the straight line M2b, and the straight line M3b each correspond to a second straight line. The angle between the first straight line and the second straight line is the angle θ.

[0065] In the flow control portion 30B of the blade 20B, the angle θ2 is greater than the angle θ1, and the angle θ3 is greater than the angle θ2. The flow control portion 30B of the blade 20B is formed between the front edge 21 and the rear edge 22 such that the angles θ1, θ2, and θ3 satisfy the following relationship: θ1 < θ2 < θ3. In the circumferential direction CD, the angle θ, which is defined between the first straight line connecting the rotation axis RA with the inner-circumference-side end of the flow control portion 30B, and the second straight line connecting the rotation axis RA with the outer-circumference-side end of the flow control portion 30B, is greater near the rear edge 22 than near the front edge 21. The flow control portion 30B is formed in the same manner even when there are four or more sectional portions S. That is, in the flow control portion 30B, the angle θ, which is defined between the first straight line connecting the rotation axis RA with the inner-circumference-side end of the flow control portion 30B, and the second straight line connecting the rotation axis RA with the outer-circumference-side end of the flow control portion 30B, is greater near the rear edge 22 than near the front edge 21.

[Advantageous Effects of Axial Fan 100B]

[0066] In the flow control portion 30B, the angle θ, which is defined between the first straight line connecting the rotation axis RA with the inner-circumference-side end of the flow control portion 30B, and the second straight line connecting the rotation axis RA with the outer-circumference-side end of the flow control portion 30B, is greater near the rear edge 22 than near the front edge 21. Because of the above-mentioned configuration of the axial fan 100B, a plane bounded by the sectional portion S and the sectional straight line W is oriented increasingly toward the inner circumference with increasing distance from the front edge 21 toward the rear edge 22. The above-mentioned configuration of the axial fan 100B makes it possible to reduce the radial flow of the fluid toward a region located closer to the outer circumference than is the flow control portion 30B. As a result, the fluid flow directed toward the outer circumferential region of the blade 20B is allowed to concentrate in the flow control portion 30B. Further, the above-mentioned configuration of the axial fan 100B makes it possible to reduce leakage of the fluid from the pressure surface 25 at an end near the outer circumference of the blade 20B. This helps to reduce growth of a blade tip vortex. Therefore, the efficiency of the axial fan 100B is improved, and the required power consumption of the axial fan 100B is reduced.

Embodiment 4.

[Axial Fan 100C]

[0067] Fig. 8 is a schematic front view of a blade 20C of an axial fan 100C according to Embodiment 4. Reference is made below to Fig. 8 to describe the configuration of the blade 20C in detail. Portions or parts of the axial fan 100C identical in configuration to those of the axial fans 100 to 100B illustrated in Figs. 1 to 7 are denoted by the same reference signs and not described below in further detail. For the axial fan 100C according to Embodiment 4, the orientation of the sectional portion S of a flow control portion 30C is specified, which differs from the orientation of the sectional portion S of the flow control portion 30C in the axial fan 100B according to Embodiment 3.

[0068] In the flow control portion 30C of the blade 20C, the angle θ2 is less than the angle θ1, and the angle θ3 is less than the angle θ2. The flow control portion 30C of the blade 20C is formed between the front edge 21 and the rear edge 22 such that the angles θ1, θ2, and θ3 satisfy the following relationship: θ3 < θ2 < θ1. In the circumferential direction CD, the angle θ, which is defined between the first straight line connecting the rotation axis RA with the inner-circumference-side end of the flow control portion 30C, and the second straight line connecting the rotation axis RA with the outer-circumference-side end of the flow control portion 30C, is less near the rear edge 22 than near the front edge 21. The flow control portion 30C is formed in the same manner even when there are four or more sectional portions S. That is, in the flow control portion 30C, the angle θ, which is defined between the first straight line connecting the rotation axis RA with the inner-circumference-side end of the flow control portion 30C, and the second straight line connecting the rotation axis RA with the outer-circumference-side end of the flow control portion 30C, is less near the rear edge 22 than near the front edge 21.

[Advantageous Effects of Axial Fan 100C]

[0069] In the flow control portion 30C, the angle θ, which is defined between the first straight line connecting the rotation axis RA with the inner-circumference-side end of the flow control portion 30C, and the second straight line connecting the rotation axis RA with the outer-circumference-side end of the flow control portion 30C, is less near the rear edge 22 than near the front edge 21. Because of the above-mentioned configuration of the axial fan 100C, a plane bounded by the sectional portion S and the sectional straight line W becomes increasingly oriented in the rotation direction DR with increasing distance from the front edge 21 toward the rear edge 22. The above-mentioned configuration of the axial fan 100C makes it possible to reduce the radial component of the fluid flow in the flow control portion 30C that is directed toward the inner circumference or the outer circumference. This allows the fluid flow to concentrate in the sectional portion S of the flow control portion 30C. Further, the above-mentioned configuration of the axial fan 100C makes it possible to reduce leakage of the fluid from the pressure surface 25 at an end near the outer circumference of the blade 20C. This helps to reduce growth of a blade tip vortex. Therefore, the efficiency of the axial fan 100C is improved, and the required power consumption of the axial fan 100C is reduced. Further, the above-mentioned configuration allows for improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 100C. This leads to reduced noise generation.

Embodiment 5.

[Axial Fan 100D]

[0070] Fig. 9 is a schematic front view of a blade 20D of an axial fan 100D according to Embodiment 5. Reference is made below to Fig. 9 to describe the configuration of the blade 20D in detail. Portions or parts of the axial fan 100D identical in configuration to those of the axial fans 100 to 100C illustrated in Figs. 1 to 8 are denoted by the same reference signs and not described below in further detail. For the axial fan 100D according to Embodiment 5, the configuration of the rear edge 22 of the blade 20D is specified.

[0071] The rear edge 22 has a projecting part 22a, which is located in a portion of the blade 20 near the rotation axis RA, and an outer-circumference-side rear edge 22b, which is located closer to the outer circumferential edge 23 of the blade 20 than is the projecting part 22a. The projecting part 22a is located near the inner circumference of the blade 20 in the radial direction. In the projecting part 22a, the rear edge is extended in the circumferential direction. That is, the projecting part 22a extends to project toward the trailing portion of the blade 20D in the rotation direction DR in comparison with the outer-circumference-side rear edge 22b.

[0072] The projecting part 22a is in the form of a flat plate, and has a substantially triangular shape when viewed parallel to the direction of the rotation axis RA. The projecting part 22a is tapered in the direction in which the projecting part 22a projects. However, the projecting part 22a may not necessarily have a substantially triangular shape. For example, the projecting part 22a may have another shape when viewed parallel to the direction of the rotation axis RA, such as a substantially trapezoidal shape and a shape made up of multiple substantially triangular shapes.

[0073] Fig. 10 is another schematic front view of the blade 20D of the axial fan 100D according to Embodiment 5. As illustrated in Fig. 10, the axial fan 100D may have a flow control portion 30D located near the outer circumference of the blade 20D in the radial direction. The flow control portion 30D is formed by one of the above-mentioned flow control portions 30, 30A, 30B, and 30C.

[Advantageous Effects of Axial Fan 100D]

[0074] The rear edge 22 has the projecting part 22a, which is located in a portion of the blade 20 near the rotation axis RA, and the outer-circumference-side rear edge 22b, which is located closer to the outer circumferential edge 23 of the blade 20 than is the projecting part 22a. The projecting part 22a extends to project toward the trailing portion of the blade 20D in the rotation direction DR in comparison with the outer-circumference-side rear edge 22b. In the axial fan 100D, the presence of the projecting part 22a, which defines a portion of the rear edge 22 near the inner circumference, allows for increased air velocity in a region that is located closer to the inner circumference than is the maximum air velocity region in the radial direction.

[0075] This results in improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 100D, which leads to reduced noise generation. By using the axial fan 100D in combination with the flow control portion 30D located near the outer circumference of the blade 20 in the radial direction, the velocity distribution of the fluid blown by the axial fan 100D is made uniform across the entire radius of the axial fan 100D.

Embodiment 6.

[Axial Fan 100E]

[0076] Fig. 11 is a conceptual diagram representing a meridian plane of an axial fan 100E according to Embodiment 6. Fig. 12 is a schematic front view of a blade 20E of the axial fan 100E according to Embodiment 6. Fig. 11 illustrates the shape of the axial fan 100E when rotated and projected onto a meridian plane that covers the rotation axis RA and the blade 20E. For the axial fan 100E, the shape of the blade 20E rotated and projected onto the meridian plane is represented by a blade projected portion 20q, and the shape of the hub 10 rotated and projected onto the meridian plane is represented by the hub projected portion 10p. Reference is made below to Figs. 11 and 12 to describe the configuration of the blade 20E in detail. Portions or parts of the axial fan 100E identical in configuration to those of the axial fans 100 to 100D illustrated in Figs. 1 to 10 are denoted by the same reference signs and not described below in further detail.

[0077] A position Q1, a position Q2, and a position Q3 shown by dotted lines in Fig. 12 each represent the position of a section perpendicular to the rotation axis RA. In the axial direction AD aligned with the rotation axis RA, the position Q1, the position Q2, and the position Q3 are in this order from an upstream region toward a downstream region in the direction of fluid flow. Portions of the axial fan 100E located in the plane of the section shown at the position Q1 represent portions of the axial fan 100E that are located at the same position in the axial direction AD aligned with the rotation axis RA. Likewise, portions of the axial fan 100E located in the plane of the section shown at the position Q2 are located at the same position in the axial direction AD aligned with the rotation axis RA. Likewise, portions of the axial fan 100E located in the plane of the section shown at the position Q3 are located at the same position in the axial direction AD aligned with the rotation axis RA. As for the relationship between each portion of the axial fan 100E located in the plane of the section shown at the position Q1, each portion of the axial fan 100E located in the plane of the section shown at the position Q2, and each portion of the axial fan 100E located in the plane of the section shown at the position Q3, these portions of the axial fan 100E are located at different positions in the axial direction AD aligned with the rotation axis RA. The position Q1, the position Q2, and the position Q3 are representative of their relative locations between the front edge 21 and the rear edge 22. Although the foregoing description of Embodiment 6 is directed to the relationship between the three positions Q1 to Q3, such positional relationship is applicable not only to the three positions Q1 to Q3 but also to four or more positions.

(Inner-circumference-side Flow Control Portion 40)

[0078] The blade 20E has an inner-circumference-side flow control portion 40. The inner-circumference-side flow control portion 40 is located near the inner circumference of the blade 20E to guide the flow of fluid on the pressure surface 25. In the circumferential direction CD, the inner-circumference-side flow control portion 40 is located at least between a midsection 29, which is located midway between the front edge 21 and the rear edge 22, and the rear edge 22. The inner-circumference-side flow control portion 40 is formed with a constant width such that in the radial direction, the inner-circumference-side flow control portion 40 is positioned to at least partially overlap a region where the projecting part 22a is provided. The inner-circumference-side flow control portion 40 is a region having an arcuate shape when viewed parallel to the rotation axis RA. The inner-circumference-side flow control portion 40 has an inner-circumference-side regional inner edge 41, and an inner-circumference-side regional outer edge 42. The inner-circumference-side regional inner edge 41 is located closer to the inner circumference than is the inner-circumference-side regional outer edge 42. The inner-circumference-side regional outer edge 42 is located closer to the outer circumference than is the inner-circumference-side regional inner edge 41. The inner-circumference-side regional inner edge 41 is located closer to the inner circumference of the axial fan 100E than is the virtual blade intermediate line 28 in the radial direction. The inner-circumference-side regional outer edge 42 is located closer to the inner circumference of the axial fan 100E than is the virtual blade intermediate line 28 in the radial direction. It is to be noted, however, that the inner-circumference-side regional outer edge 42 may be located closer to the outer circumference of the axial fan 100E than is the virtual blade intermediate line 28 in the radial direction.

[0079] The inner-circumference-side regional inner edge 41 is formed in an arcuate shape, and located at a constant distance from the rotation axis RA in the radial direction of the axial fan 100E. Likewise, the inner-circumference-side regional outer edge 42 is formed in an arcuate shape, and located at a constant distance from the rotation axis RA in the radial direction of the axial fan 100E. The inner-circumference-side flow control portion 40 is a region located between the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42. The inner-circumference-side flow control portion 40 is located in at least part of the portion between the front edge 21 and the rear edge 22 in the circumferential direction CD of the axial fan 100E. That is, the inner-circumference-side flow control portion 40 extends in the blade 20E in the radial direction of the axial fan 100E and also in the circumferential direction CD.

[0080] The inner-circumference-side flow control portion 40 has a width in the radial direction that is constant at any position in the circumferential direction CD of the axial fan 100E. That is, in the inner-circumference-side flow control portion 40, the distance between the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 in the radial direction is constant at any position in the circumferential direction CD of the axial fan 100E. However, each of the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 may not necessarily be located at the constant distance from the rotation axis RA at any position in the circumferential direction CD of the axial fan 100E. In this case, the axial fan 100E has a width in the radial direction that varies with the position in the circumferential direction CD of the axial fan 100E.

[0081] The inner-circumference-side flow control portion 40 is located relatively close to the inner circumference in the radial direction of the blade 20E. For example, the inner-circumference-side flow control portion 40 has an inner-circumference-side virtual regional intermediate line 43 that is located closer to the inner circumference than is the virtual blade intermediate line 28 located between the outer circumferential edge 23 and the inner circumferential edge 24, that is, the virtual blade intermediate line 28 extending through the middle of the blade 20E in the radial direction. Desirably, the inner-circumference-side flow control portion 40 is provided in a region that is equal in size in the radial direction to the region where the projecting part 22a of the rear edge 22 is provided. However, the inner-circumference-side flow control portion 40 may not necessarily be formed in a region that is equal in size in the radial direction to the region where the projecting part 22a of the rear edge 22 is provided. For example, the inner-circumference-side flow control portion 40 may be provided in a region that is smaller in the radial direction than the region where the projecting part 22a of the rear edge 22 is provided, or may be formed in a region that is larger in the radial direction than the region where the projecting part 22a of the rear edge 22 is provided. In the radial direction, at least part of the inner-circumference-side flow control portion 40 only has to be located in a region where the projecting part 22a of the rear edge 22 is provided.

[0082] In the inner-circumference-side flow control portion 40, in at least part of a portion of the blade 20E between the front edge 21 and the rear edge 22 in the circumferential direction CD, the blade plate of the blade 20E is bent and cambered such that the section of the blade taken in the radial direction is convex in a direction opposite to the rotation direction DR of the axial fan 100E. In the inner-circumference-side flow control portion 40, in at least part of the portion of the blade 20E between the front edge 21 and the rear edge 22 in the circumferential direction CD, the blade plate is bent and cambered to be convex upstream in the direction of fluid flow. That is, in the inner-circumference-side flow control portion 40, in at least part of the axial fan 100E in the circumferential direction CD, the pressure surface 25 of the blade 20E is concave, and the suction surface 26 of the blade 20E in the corresponding part of the axial fan 100E is convex.

[0083] An inner-circumference-side sectional portion SI shown by a dotted line in Fig. 12 represents a section of the blade 20E in the inner-circumference-side flow control portion 40. The inner-circumference-side sectional portion SI is located between the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42, and is a section perpendicular to the rotation axis RA. The inner-circumference-side sectional portion SI is bent to have a concave part of the pressure surface 25, and a convex part of the suction surface 26. The inner-circumference-side sectional portion SI represents a section of the inner-circumference-side flow control portion 40 perpendicular to the rotation axis RA. The inner-circumference-side sectional portion SI is bent to be convex in a direction opposite to the rotation direction DR. Further, the inner-circumference-side sectional portion SI is bent to be convex upstream in the direction of flow AF of the fluid. The inner-circumference-side sectional portion SI is bent to have a concave part of the pressure surface 25, and a convex part of the suction surface 26. In the radial direction (Y-axis direction) of the axial fan 100E, one end of the inner-circumference-side sectional portion SI located near the inner circumference corresponds to the inner-circumference-side regional inner edge 41, and the other end of the sectional portion S located near the outer circumference corresponds to the inner-circumference-side regional outer edge 42.

[0084] An inner-circumference-side sectional portion SI1 shown by a dotted line in Fig. 12 represents the inner-circumference-side sectional portion SI of the blade 20E in the inner-circumference-side flow control portion 40 at the position Q1 illustrated in Fig. 11. An inner-circumference-side sectional portion SI2 shown by a dotted line in Fig. 12 represents the inner-circumference-side sectional portion SI of the blade 20E in the inner-circumference-side flow control portion 40 at the position Q2 illustrated in Fig. 11. An inner-circumference-side sectional portion SI3 shown by a dotted line in Fig. 12 represents the inner-circumference-side sectional portion SI of the blade 20E in the inner-circumference-side flow control portion 40 at the position Q3 illustrated in Fig. 11. More specifically, the inner-circumference-side sectional portion SI1 represents a section of the inner-circumference-side flow control portion 40 taken at the position Q1 in the axial direction AD and perpendicular to the rotation axis RA. The inner-circumference-side sectional portion SI2 represents a section of the inner-circumference-side flow control portion 40 taken at the position Q2 in the axial direction AD and perpendicular to the rotation axis RA. The inner-circumference-side sectional portion SI3 represents a section of the inner-circumference-side flow control portion 40 taken at the position Q3 in the axial direction AD and perpendicular to the rotation axis RA. In the radial direction of the axial fan 100E, one end of each of the inner-circumference-side sectional portions SI1, S12, and SI3 that is located near the inner circumference corresponds to the inner-circumference-side regional inner edge 41. The other end of each of the inner-circumference-side sectional portions SI1, SI2, and SI3 that is located near the outer circumference corresponds to the inner-circumference-side regional outer edge 42.

[0085] In the axial direction AD aligned with the rotation axis RA, the inner-circumference-side sectional portion S11, the inner-circumference-side sectional portion SI2, and the inner-circumference-side sectional portion SI3 are the inner-circumference-side sectional portions SI that are positioned in this order from an upstream region toward a downstream region in the direction of fluid flow. In the circumferential direction CD of the axial fan 100E, the inner-circumference-side sectional portion S11, the inner-circumference-side sectional portion S12, and the inner-circumference-side sectional portion SI3 are the inner-circumference-side sectional portions SI that are positioned in this order in a direction from the front edge 21 toward the rear edge 22.

[0086] In each inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40 located at the same position in the axial direction AD of the axial fan 100E, a straight line connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side straight line WI. In the inner-circumference-side sectional portion SI, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the inner-circumference-side straight line WI connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as a projection amount LI. The inner-circumference-side projection amount LI represents the distance in the normal direction from the inner-circumference-side straight line WI to an inner-circumference-side deepest part 45 of the inner-circumference-side sectional portion SI where the blade 20E is most convex. The inner-circumference-side deepest part 45 is the most concave part of the pressure surface 25 in the inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40. That is, the inner-circumference-side deepest part 45 is a part where the inner-circumference-side straight line WI and the pressure surface 25 are farthest from each other in the inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40. In other words, the inner-circumference-side deepest part 45 is the most projecting part of the suction surface 26 in the inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40, and represents the vertex part of the convex shape defining the inner-circumference-side sectional portion SI.

[0087] As with the above description of the inner-circumference-side sectional portion SI, in the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40 at the position Q1, a straight line connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side straight line WI1. In the inner-circumference-side sectional portion SI1, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the inner-circumference-side straight line WI1 connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side projection amount LI1. The inner-circumference-side projection amount LI1 represents the distance in the normal direction from the inner-circumference-side straight line WI1 to an inner-circumference-side deepest part 45a of the inner-circumference-side sectional portion SI1 where the blade 20E is most convex. The inner-circumference-side deepest part 45a is the most concave part of the pressure surface 25 in the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40. That is, the inner-circumference-side deepest part 45a is a part where the inner-circumference-side straight line WI1 and the pressure surface 25 are farthest from each other in the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40. In other words, the inner-circumference-side deepest part 45a is the most projecting part of the suction surface 26 in the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40, and represents the vertex part of the convex shape defining the inner-circumference-side sectional portion S11.

[0088] As with the above description of the inner-circumference-side sectional portion SI, in the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 40 at the position Q2, a straight line connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side straight line WI2. In the inner-circumference-side sectional portion SI2, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the inner-circumference-side straight line WI2 connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side projection amount LI2. The inner-circumference-side projection amount LI2 represents the distance in the normal direction from the inner-circumference-side straight line WI2 to an inner-circumference-side deepest part 45b of the inner-circumference-side sectional portion SI2 where the blade 20E is most convex. The inner-circumference-side deepest part 45b is the most concave part of the pressure surface 25 in the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 40. That is, the inner-circumference-side deepest part 45b is a part where the inner-circumference-side straight line WI2 and the pressure surface 25 are farthest from each other in the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 40. In other words, the inner-circumference-side deepest part 45b is the most projecting part of the suction surface 26 in the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 40, and represents the vertex part of the convex shape defining the inner-circumference-side sectional portion SI2.

[0089] As with the above description of the inner-circumference-side sectional portion SI, in the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 40 at the position Q3, a straight line connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side straight line WI3. In the inner-circumference-side sectional portion SI3, the distance to a portion of the pressure surface 25 that is farthest in the normal direction from the inner-circumference-side straight line WI3 connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 is defined as an inner-circumference-side projection amount LI3. The inner-circumference-side projection amount LI3 represents the distance in the normal direction from the inner-circumference-side straight line WI3 to an inner-circumference-side deepest part 45c of the inner-circumference-side sectional portion SI3 where the blade 20E is most convex. The inner-circumference-side deepest part 45c is the most concave part of the pressure surface 25 in the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 40. That is, the inner-circumference-side deepest part 45c is a part where the inner-circumference-side straight line WI3 and the pressure surface 25 are farthest from each other in the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 40. In other words, the inner-circumference-side deepest part 45c is the most projecting part of the suction surface 26 in the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 40, and represents the vertex part of the convex shape defining the inner-circumference-side sectional portion SI3.

[0090] The inner-circumference-side flow control portion 40 of the blade 20E is formed between the front edge 21 and the rear edge 22 such that the inner-circumference-side projection amount LI decreases with increasing distance from the front edge 21 toward the rear edge 22. That is, the inner-circumference-side flow control portion 40 of the blade 20E is formed between the front edge 21 and the rear edge 22 such that bending of the blade 20E that is directed upstream decreases with increasing distance from the front edge 21 toward the rear edge 22. In other words, in the inner-circumference-side flow control portion 40 of the blade 20E, the concave part of the pressure surface 25 decreases in depth with increasing distance from the front edge 21 toward the rear edge 22. When the inner-circumference-side flow control portion 40 of the blade 20E has a region of decreasing inner-circumference-side projection amount LI, the region of decreasing inner-circumference-side projection amount LI is located at least in a region of the blade 20E between the midsection 29 and the rear edge 22. The midsection 29 of the blade 20E is located midway between the front edge 21 and the rear edge 22 in the direction of the rotation axis RA.

[0091] For example, as illustrated in Fig. 12, in the inner-circumference-side flow control portion 40 of the blade 20E, the inner-circumference-side projection amount LI2 is less than the inner-circumference-side projection amount LI1, and the inner-circumference-side projection amount LI3 is less than the inner-circumference-side projection amount LI2. The inner-circumference-side flow control portion 40 of the blade 20E is formed between the front edge 21 and the rear edge 22 such that the inner-circumference-side projection amounts LI1, LI2, and LI3 satisfy the following relationship: LI3 < LI2 < LI1. The inner-circumference-side flow control portion 40 is formed in the same manner even when there are four or more inner-circumference-side sectional portions SI. That is, in the circumferential direction CD, the inner-circumference-side projection amount LI near the rear edge 22 is less than the inner-circumference-side projection amount LI near the front edge 21.

[0092] The inner-circumference-side flow control portion 40 of the blade 20E may not necessarily be formed between the front edge 21 and the rear edge 22 such that inner-circumference-side projection amount LI decreases with increasing distance from the front edge 21 toward the rear edge 22. The inner-circumference-side flow control portion 40 of the blade 20E only has to be formed between the front edge 21 and the rear edge 22 such that the inner-circumference-side projection amount LI does not increase with increasing distance from the front edge 21 toward the rear edge 22. Accordingly, the inner-circumference-side flow control portion 40 may have a region where the inner-circumference-side projection amount LI remains constant with increasing distance from the front edge 21 toward the rear edge 22. Such a region of constant inner-circumference-side projection amount LI may be present in either a portion or entirety of a region of the blade 20E from the front edge 21 to the rear edge 22. When the inner-circumference-side flow control portion 40 of the blade 20E has a region of constant inner-circumference-side projection amount LI, the region of constant inner-circumference-side projection amount LI is located at least in a region of the blade 20E between the midsection 29 and the rear edge 22.

[0093] For example, in the inner-circumference-side flow control portion 40 of the blade 20E, the inner-circumference-side projection amount LI1 and the inner-circumference-side projection amount LI2 may be equal to each other (L1 = L2). Alternatively, in the inner-circumference-side flow control portion 40 of the blade 20E, the inner-circumference-side projection amount LI2 and the inner-circumference-side projection amount LI3 may be equal to each other (L2 = L3). Alternatively, in the inner-circumference-side flow control portion 40 of the blade 20E, the projection amount L1, the inner-circumference-side projection amount LI2, and the inner-circumference-side projection amount LI3 may be equal to each other (L1 = L2 = L3).

[0094] That is, the blade 20E has, between the front edge 21 and the rear edge, at least a region of constant inner-circumference-side projection amount LI in a portion of the blade 20E from the midsection 29 to the rear edge 22, or at least a region of decreasing inner-circumference-side projection amount LI in a portion of the blade 20E with increasing distance from the midsection 29 toward the rear edge 22. That is, the blade 20E has a region where the inner-circumference-side projection amount LI does not change with increasing distance from the front edge 21 toward the rear edge 22, or a region where the inner-circumference-side projection amount LI decreases with increasing distance from the front edge 21 toward the rear edge 22.

[0095] Fig. 13 is a schematic front view of a blade 20F of an axial fan 100F according to a modification of Embodiment 6. The axial fan 100F has the inner-circumference-side flow control portion 40 located near the inner circumference of the blade 20F, and the flow control portion 30 located near the outer circumference of the blade 20F. The flow control portion 30 may be one of the flow control portions 30A to 30D. As described above, the position Q1, the position Q2, and the position Q3 in Fig.

2 are representative of their relative locations between the front edge 21 and the rear edge 22. The position Q1, the position Q2, and the position Q3 of the inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40, which are illustrated in Fig. 13, may be respectively the same as or different from the position P1, the position P2, and the position P3 of the sectional portion S of the flow control portion 30.

[Advantageous Effects of Axial Fans 100E and 100F]

[0096] The blade 20E has a region where the inner-circumference-side projection amount LI does not change with increasing distance from the front edge 21 toward the rear edge 22, or a region where the inner-circumference-side projection amount LI decreases with increasing distance from the front edge 21 toward the rear edge 22. The above-mentioned configuration of the axial fan 100E helps to prevent the fluid flow from being guided in the radial direction toward the inner-circumference-side flow control portion 40, which is located near the inner circumference of the blade 20E, from a region that is located outside the blade 20E and closer to the outer circumference than is the inner-circumference-side flow control portion 40 and where work is efficiently done on the fluid. At the same time, the above-mentioned configuration makes it possible to increase air velocity near the inner circumference. The above-mentioned configuration therefore makes it possible to improve the uniformity of the velocity distribution of the airflow FL blown by the axial fan 100E, and consequently reduce noise generation, without necessitating an increase in the required power consumption of the axial fan 100E.

[0097] The blade 20F has a region where the inner-circumference-side projection amount LI does not change with increasing distance from the front edge 21 toward the rear edge 22, or a region where the inner-circumference-side projection amount LI decreases with increasing distance from the front edge 21 toward the rear edge 22. The above-mentioned configuration of the axial fan 100F helps to prevent the fluid flow from being guided in the radial direction toward the inner-circumference-side flow control portion 40, which is located near the inner circumference of the blade 20F, from a region that is located outside the blade 20F and closer to the outer circumference than is the inner-circumference-side flow control portion 40 and where work is efficiently done on the fluid. At the same time, the above-mentioned configuration makes it possible to increase air velocity near the inner circumference. The above-mentioned configuration therefore makes it possible to improve the uniformity of the velocity distribution of the airflow FL blown by the axial fan 100F, and consequently reduce noise generation, without necessitating an increase in the required power consumption of the axial fan 100F.

[0098] Further, with the flow control portion 30 viewed parallel to the direction of the rotation axis RA, the virtual regional intermediate line 33, which extends through the middle of the region between the regional inner edge 31 and the regional outer edge 32, is located closer to the outer circumference than is the virtual blade intermediate line 28, which extends through the middle of the blade 20 between the inner circumferential edge 24 and the outer circumferential edge 23. The axial fan 100F has the sectional portion S that is located near the outer circumference of the blade 20F and is convex from a downstream region toward an upstream region in the direction of the fluid flow to be created by the blade 20. As a result, as represented by the fluid flow MF illustrated in Fig. 13, the fluid is guided from a region located closer to the inner circumference than is the sectional portion S, toward the sectional portion S located in an outer circumferential region where work is efficiently done on the fluid. This helps to reduce the required power consumption of the axial fan 100F. Further, the sectional portion S of the axial fan 100F has the projection amount L that increases with increasing distance from the front edge 21 toward the rear edge 22 in the direction of fluid flow. This allows the fluid on the pressure surface 25 to easily flow along the sectional portion S, which causes the fluid flow on the pressure surface 25 to concentrate in the sectional portion S. The above-mentioned configuration of the axial fan 100F helps to reduce leakage of the fluid from the pressure surface 25 at the outer circumferential end of the blade 20F, and consequently reduce growth of a blade tip vortex.

Embodiment 7.

[Axial Fan 100G]

[0099] Fig. 14 is a schematic front view of a blade 20G of an axial fan 100G according to Embodiment 7. Reference is made below to Fig. 14 to describe the configuration of the blade 20G in detail. Portions or parts of the axial fan 100G identical in configuration to those of the axial fans 100 to 100F illustrated in Figs. 1 to 13 are denoted by the same reference signs and not described below in further detail. Although the flow control portion 30 is not depicted in Fig. 14, as with the axial fan 100F according to Embodiment 6 illustrated in Fig. 13, the axial fan 100G may have the flow control portion 30 located near the outer circumference of the axial fan 100G. When the axial fan 100G has the flow control portion 30, the flow control portion 30 is simply required to be one of the flow control portions 30 to 30D.

(Inner-circumference-side Flow Control Portion 40G)

[0100] The blade 20G has an inner-circumference-side flow control portion 40G. The inner-circumference-side flow control portion 40G is located near the inner circumference of the blade 20G to guide the flow of fluid along the pressure surface 25. The inner-circumference-side flow control portion 40G is a region having an arcuate shape when viewed parallel to the rotation axis RA. The inner-circumference-side flow control portion 40 has the inner-circumference-side regional inner edge 41 defining an edge near the inner circumference, and the inner-circumference-side regional outer edge 42 defining an edge near the outer circumference. In the radial direction, at least part of the inner-circumference-side flow control portion 40G is provided in a region where the projecting part 22a of the rear edge 22 is provided. Desirably, the inner-circumference-side flow control portion 40G is provided in a region that is equal in size in the radial direction to the region where the projecting part 22a of the rear edge 22 is provided. The inner-circumference-side flow control portion 40G differs from the inner-circumference-side flow control portion 40 in features related to the inner-circumference-side projection amount LI.

[0101] The inner-circumference-side flow control portion 40G of the blade 20G is formed between the front edge 21 and the rear edge 22 such that the inner-circumference-side projection amount LI increases with increasing distance from the front edge 21 toward the rear edge 22. That is, the inner-circumference-side flow control portion 40G of the blade 20G is formed between the front edge 21 and the rear edge 22 such that bending of the blade 20G that is directed upstream increases with increasing distance from the front edge 21 toward the rear edge 22. In other words, in the inner-circumference-side flow control portion 40G of the blade 20G, the concave part of the pressure surface 25 increases in depth with increasing distance from the front edge 21 toward the rear edge 22, from a region located outside the inner-circumference-side flow control portion 40G in the radial direction. In the inner-circumference-side flow control portion 40G of the blade 20G, such a region of increasing inner-circumference-side projection amount LI is present at least in a portion of the blade 20G between the mid-section 29 and the rear edge 22.

[0102] For example, as illustrated in Fig. 14, in the inner-circumference-side flow control portion 40G of the blade 20G, the inner-circumference-side projection amount LI2 is greater than the inner-circumference-side projection amount LI1, and the inner-circumference-side projection amount LI3 is greater than the inner-circumference-side projection amount LI2. The inner-circumference-side flow control portion 40G of the blade 20G is formed between the front edge 21 and the rear edge 22 such that the inner-circumference-side projection amounts LI1, LI2, and LI3 satisfy the following relationship: LI1 < LI2 < LI3. The inner-circumference-side flow control portion 40G is formed in the same manner even when there are four or more inner-circumference-side sectional portions SI. That is, in the circumferential direction CD, the inner-circumference-side projection amount LI near the rear edge 22 is greater than the inner-circumference-side projection amount LI near the front edge 21.

[Advantageous Effects of Axial Fan 100G]

[0103] Fig. 15 is a conceptual diagram for explaining the configuration of an outdoor unit 50L including the axial fan 100G according to Embodiment 7. The outdoor unit 50L includes a heat exchanger 68, a compressor 64, and the axial fan 100G. The interior of the outdoor unit 50L is divided by a partition plate 51g, which is a wall element, into an air-sending chamber 56 in which the heat exchanger 68 and the axial fan 100G are installed, and a machine chamber 57 in which the compressor 64 is installed. The axial fan 100G is connected to a fan motor 61. The fan motor 61 is mounted to a motor support 69.

[0104] In some cases, designing the heat exchanger 68 of the outdoor unit 50L to operate at high pressure drop results in increased contribution of the outer circumferential region of the axial fan 100G to work, which may impede the inflow of fluid toward the inner circumference of the axial fan 100G. This may lead to reduced inflow of fluid toward the inner circumference of the axial fan 100G. Further, when the presence of a structure such as the motor support 69 disposed upstream of the axial fan 100G in the outdoor unit 50L impedes the inflow of fluid toward the inner circumference of the axial fan 100G, this may result in reduced inflow of fluid toward the inner circumference of the axial fan 100G. In Fig. 15, a flow FL2 represents an exemplary fluid flow affected by the motor support 69. When the inflow of fluid toward the inner circumference of the axial fan 100G in the outdoor unit 50L is impeded as in the above-mentioned cases, the inflow of fluid toward the inner circumference of the axial fan 100G decreases. This may result in increased load on the axial fan 100G, and consequently increased power consumption.

[0105] The inner-circumference-side flow control portion 40G of the blade 20G is formed between the front edge 21 and the rear edge 22 such that the inner-circumference-side projection amount LI increases with increasing distance from the front edge 21 toward the rear edge 22. The inner-circumference-side flow control portion 40G provided to the axial fan 100G makes it possible to guide a fluid flow F3 from an outer circumferential region of the blade 20G toward the inner circumference of the blade 20G. This leads to increased efficiency of the axial fan 100G. In the inner-circumference-side flow control portion 40G, the inner-circumference-side projection amount LI increases with increasing distance from the front edge 21 toward the rear edge 22. This configuration allows the inner-circumference-side flow control portion 40G to guide the fluid flow gradually toward the inner circumference after work is effectively done in a region located near the front edge 21 and closer to the outer circumference than is the inner-circumference-side flow control portion 40G. The above-mentioned configuration helps to ensure a sufficient amount of work in a region of the axial fan 100G located closer to the outer circumference than is the inner-circumference-side flow control portion 40G, while allowing for increased fluid inflow toward the inner circumference to thereby reduce the load near the inner circumference. This helps to increase the efficiency of the axial fan 100G, and consequently reduce the required power consumption of the axial fan 100G. Further, the above-mentioned configuration leads to improved uniformity of the velocity distribution of the airflow FL blown by the axial fan 100G, and consequently to reduced noise generation.

Embodiment 8.

[Axial Fan 100H]

[0106] Fig. 16 is a schematic front view of a blade 20H of an axial fan 100H according to Embodiment 8. Reference is made below to Fig. 16 to describe the configuration of the blade 20H in detail. Portions or parts of the axial fan 100H identical in configuration to those of the axial fans 100 to 100G illustrated in Figs. 1 to 15 are denoted by the same reference signs and not described below in further detail. For the axial fan 100H according to Embodiment 8, the location of the inner-circumference-side deepest part 45 of an inner-circumference-side flow control portion 40H is specified. Although the flow control portion 30 is not depicted in Fig. 16, as with the axial fan 100F according to Embodiment 6 illustrated in Fig. 13, the axial fan 100H may have the flow control portion 30 located near the outer circumference of the axial fan 100H. When the axial fan 100H has the flow control portion 30, the flow control portion 30 is simply required to be one of the flow control portions 30 to 30D.

[0107] As described above, the inner-circumference-side deepest part 45 is the most concave part of the pressure surface 25 in the inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40. Further, the inner-circumference-side deepest part 45 is the most projecting part of the suction surface 26 in the inner-circumference-side sectional portion SI of the inner-circumference-side flow control portion 40, and represents the vertex part of the convex shape defining the inner-circumference-side sectional portion SI. The inner-circumference-side deepest part 45a corresponds to the inner-circumference-side deepest part 45 of the inner-circumference-side sectional portion SI1 in the inner-circumference-side flow control portion 40H. The inner-circumference-side deepest part 45b corresponds to the inner-circumference-side deepest part 45 of the inner-circumference-side sectional portion SI2 in the inner-circumference-side flow control portion 40H. The inner-circumference-side deepest part 45c corresponds to the inner-circumference-side deepest part 45 of the inner-circumference-side sectional portion SI3 in the inner-circumference-side flow control portion 40H. In the circumferential direction CD of the axial fan 100H, the inner-circumference-side sectional portion S11, the inner-circumference-side sectional portion SI2, and the inner-circumference-side sectional portion SI3 are the inner-circumference-side sectional portions SI that are positioned in this order in a direction from the front edge 21 to the rear edge 22.

[0108] A distance RI1 in Fig. 16 is the distance between the rotation axis RA and the inner-circumference-side deepest part 45a in the radial direction of the axial fan 100H. Likewise, a distance RI2 is the distance between the rotation axis RA and the inner-circumference-side deepest part 45b in the radial direction of the axial fan 100H. Likewise, a distance RI3 is the distance between the rotation axis RA and the inner-circumference-side deepest part 45c in the radial direction of the axial fan 100H. In the inner-circumference-side flow control portion 40H of the axial fan 100H, the distance RI2 is less than the distance RI1, and the distance RI3 is less than the distance RI2. That is, in the axial fan 100H, the distances RI1, RI2, and RI3 have the following relationship: RI3 < RI2 < RI1. In the inner-circumference-side flow control portion 40H of the axial fan 100H, the inner-circumference-side deepest part 45 is positioned further toward the rotation axis RA in the radial direction with increasing distance from the front edge 21 toward the rear edge 22 in the circumferential direction. In the inner-circumference-side flow control portion 40H, with increasing distance from the front edge 21 toward the rear edge 22 in the circumferential direction CD, the inner-circumference-side deepest part 45 is positioned further toward the inner circumference from a location near the outer circumference in the radial direction.

[Advantageous Effects of Axial Fan 100H]

[0109] In the inner-circumference-side flow control portion 40H of the axial fan 100H, with increasing distance from the front edge 21 toward the rear edge 22 in the circumferential direction, the inner-circumference-side deepest part 45 is positioned further toward the inner circumference from a location near the outer circumference in the radial direction. The fluid flow along the pressure surface 25 of the blade 20 caused by rotation of the axial fan 100 concentrates most at the inner-circumference-side deepest part 45 of the inner-circumference-side sectional portion SI on the pressure surface 25 of the blade 20. Accordingly, because of the above-mentioned configuration of the axial fan 100H in which the inner-circumference-side deepest part 45 is positioned further toward the inner circumference in the radial direction with increasing distance from the front edge 21 toward the rear edge 22, more fluid flow is guided toward the inner circumference of the axial fan 100H. The increased fluid inflow toward the inner circumference of the axial fan 100H helps to increase efficiency, and consequently reduce required power consumption. The above-mentioned configuration also allows for improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 100H. This leads to reduced noise generation.

Embodiment 9.

[Axial Fan 1001]

[0110] Fig. 17 is a schematic front view of a blade 20I of an axial fan 1001 according to Embodiment 9. Reference is made below to Fig. 17 to describe the configuration of the blade 20I in detail. Portions or parts of the axial fan 1001 identical in configuration to those of the axial fans 100 to 100G illustrated in Figs. 1 to 16 are denoted by the same reference signs and not described below in further detail. For the axial fan 1001 according to Embodiment 9, the orientation of the inner-circumference-side sectional portion SI of an inner-circumference-side flow control portion 401 is specified.

[0111] The inner-circumference-side straight line WI1 corresponds to the inner-circumference-side straight line WI connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 in the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40I at the position Q1 illustrated in Fig. 11. In this case, the intersection of the inner-circumference-side straight line WI1 and the inner-circumference-side regional inner edge 41 is defined as an inner-circumference-side end W1d, and the intersection of the inner-circumference-side straight line WI1 and the inner-circumference-side regional outer edge 42 is defined as an outer-circumference-side end W1e. The inner-circumference-side end W1d is an end of the inner-circumference-side straight line WI1 located near the inner circumference in the radial direction. The outer-circumference-side end W1e is an end of the inner-circumference-side straight line WI1 located near the outer circumference in the radial direction. In the circumferential direction, the outer-circumference-side end W1e is located closer to the front edge 21 than is the inner-circumference-side end W1d, and the inner-circumference-side end W1d is located closer to the rear edge 22 than is the outer-circumference-side end W1e. That is, in the inner-circumference-side flow control portion 40I, the outer-circumference-side end W1e is located closer to the leading portion of the axial fan 1001 in the rotation direction DR than is the inner-circumference-side end W1d.

[0112] A straight line passing the rotation axis RA and the inner-circumference-side end W1d is defined as a straight line M1d, and a straight line passing the rotation axis RA and the outer-circumference-side end W1e is defined as a straight line M1e. The angle between the straight line M1d and the straight line M1e in the circumferential direction is defined as the angle $\theta 1$. The angle $\Phi 1$ is an angle defined between the two straight lines, that is, the straight line M1d connecting the rotation axis RA, which is at the center of the axial fan 1001, with the inner-circumference-side end W1d of the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40I, and the straight line M1e connecting the rotation axis RA with the outer-circumference-side end W1e of the inner-circumference-side sectional portion SI1 of the inner-circumference-side flow control portion 40I.

[0113] Likewise, the inner-circumference-side straight line WI2 corresponds to the inner-circumference-side straight line WI connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 in the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 40I at the position Q2 illustrated in Fig. 11. In this case, the intersection of the inner-circumference-side straight line WI2 and the inner-circumference-side regional inner edge 41 is defined as an inner-circumference-side end W2d, and the intersection of the inner-circumference-side straight line WI2 and the inner-circumference-side regional outer edge 42 is defined as an outer-circumference-side end W2e. The inner-circumference-side end W2d is an end of the inner-circumference-side straight line WI2 located near the inner circumference in the radial direction. The outer-circumference-side end W2e is an end of the inner-circumference-side straight line WI2 located near the outer circumference in the radial direction. In the circumferential direction, the outer-circumference-side end W2e is located closer to the front edge 21 than is the inner-circumference-side end W2d, and the inner-circumference-side end W2d is located closer to the rear edge 22 than is the outer-circumference-side end W2e. That is, in the inner-circumference-side flow control portion 40I, the outer-circumference-side end W2e is located closer to the leading portion of the axial fan 1001 in the rotation direction DR than is the inner-circumference-side end W2d.

[0114] A straight line passing the rotation axis RA and the inner-circumference-side end W2d is defined as a straight line M2d, and a straight line passing the rotation axis RA and the outer-circumference-side end W2e is defined as a straight line M2e. The angle between the straight line M2d and the straight line M2e in the circumferential direction is defined as the angle $\Phi 2$. The angle $\Phi 2$ is an angle defined between the two straight lines, that is, the straight line M2d connecting the rotation axis RA, which is at the center of the axial fan 1001, with the inner-circumference-side end W2d of the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 401, and the straight line M2e connecting the rotation axis RA with the outer-circumference-side end W2e of the inner-circumference-side sectional portion SI2 of the inner-circumference-side flow control portion 401.

[0115] Likewise, the inner-circumference-side straight line WI3 corresponds to the inner-circumference-side straight line WI connecting the inner-circumference-side regional inner edge 41 and the inner-circumference-side regional outer edge 42 in the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 40I at the position Q3 illustrated in Fig. 11. In this case, the intersection of the inner-circumference-side straight line WI3 and the inner-circumference-side regional inner edge 41 is defined as an inner-circumference-side end W3d, and the intersection of the inner-circumference-side straight line WI3 and the inner-circumference-side regional outer edge 42 is defined as an outer-circumference-side end W3e. The inner-circumference-side end W3d is an end of the inner-circumference-side straight line WI3 located near the inner circumference in the radial direction. The outer-circumference-side end W3e is an end of the inner-circumference-side straight line WI3 located near the outer circumference in the radial direction. In the circumferential direction, the outer-circumference-side end W3e is located closer to the front edge 21 than is the inner-circumference-side end W3d, and the inner-circumference-side end W3d is located closer to the rear edge 22 than is the outer-circumference-side end W3e. That is, in the inner-circumference-side flow control portion 40I, the outer-circumference-side end W3e is located closer to the leading portion of the axial fan 1001 in the rotation direction DR than is the inner-circumference-side end W3d.

[0116] A straight line passing the rotation axis RA and the inner-circumference-side end W3d is defined as a straight line M3d, and a straight line passing the rotation axis RA and the outer-circumference-side end W3e is defined as a straight line M3e. The angle between the straight line M3d and the straight line M3e in the circumferential direction is defined as the angle Φ3. The angle Φ3 is an angle defined between the two straight lines, that is, the straight line M3d connecting the rotation axis RA, which is at the center of the axial fan 1001, with the inner-circumference-side end W3d of the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 401, and the straight line M3e connecting the rotation axis RA with the outer-circumference-side end W3e of the inner-circumference-side sectional portion SI3 of the inner-circumference-side flow control portion 401.

[0117] The inner-circumference-side end W1d, the inner-circumference-side end W2d, and the inner-circumference-side end W3d each correspond to a second inner-circumference-side end, and the outer-circumference-side end W1e, the outer-circumference-side end W2e, and the outer-circumference-side end W3e each correspond to a second outer-circumference-side end. The straight line M1d, the straight line M2d, and the straight line M3d each correspond to a first inner-circumference-side straight line, and the straight line M1e, the straight line M2e, and the straight line M3e each correspond to a second inner-circumference-side straight line. The angle between the first inner-circumference-side straight line and the second inner-circumference-side straight line is the angle Φ.

[0118] In the inner-circumference-side flow control portion 40I of the blade 20I, the angle Φ2 is greater than the angle Φ1, and the angle Φ3 is greater than the angle Φ2. The inner-circumference-side flow control portion 40I of the blade 20I is formed between the front edge 21 and the rear edge 22 such that the angles Φ1, Φ2, and Φ3 satisfy the following relationship: Φ1 < Φ2 < Φ3. In the circumferential direction CD, the angle Φ, which is defined between the first inner-circumference-side straight line connecting the rotation axis RA with the inner-circumference-side end of the inner-circumference-side flow control portion 40I, and the second inner-circumference-side straight line connecting the rotation axis RA with the outer-circumference-side end of the inner-circumference-side flow control portion 401, is greater near the rear edge 22 than near the front edge 21. The relationship between these angles Φ is the same even when the inner-circumference-side flow control portion 40I has four or more inner-circumference-side sectional portions SI. That is, the angle Φ, which is defined between the first inner-circumference-side straight line connecting the rotation axis RA with the inner-circumference-side end of the inner-circumference-side flow control portion 40I, and the second inner-circumference-side straight line connecting the rotation axis RA with the outer-circumference-side end of the inner-circumference-side flow control portion 40I, is greater near the rear edge 22 than near the front edge 21.

[Advantageous Effects of Axial Fan 1001]

[0119] In the inner-circumference-side flow control portion 401, the angle Φ, which is defined between the first inner-circumference-side straight line connecting the rotation axis RA with the inner-circumference-side end of the inner-circumference-side flow control portion 401, and the second inner-circumference-side straight line connecting the rotation axis RA with the outer-circumference-side end of the inner-circumference-side flow control portion 401, is greater near the rear edge 22 than near the front edge 21. Because of the above-mentioned configuration of the axial fan 1001, a plane bounded by the inner-circumference-side sectional portion SI and the inner-circumference-side straight line WI is oriented increasingly toward the inner circumference with increasing distance from the front edge 21 toward the rear edge 22. This allows the fluid flow to be guided toward the inner circumference of the axial fan 1001. The increased fluid inflow toward the inner circumference of the axial fan 100I helps to increase efficiency, and consequently reduce required power consumption. The above-mentioned configuration also allows for improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 1001. This leads to reduced noise generation.

Embodiment 10.

[Axial Fan 100J]

[0120] Fig. 18 is a conceptual diagram, as viewed from top, of an outdoor unit 50 including an axial fan 100J according to Embodiment 10. Reference is made below to Fig. 18 to describe the configuration of a blade 20J of the axial fan 100J in detail. Portions or parts of the axial fan 100J identical in configuration to those of the axial fan 100 or other axial fans illustrated in Figs. 1 to 17 are denoted by the same reference signs and not described below in further detail. For the axial fan 100J according to Embodiment 10, the configuration of the rear edge 22 is further specified. As illustrated in Fig. 18, when the axial fan 100J activates, a fluid F flows in the air-sending chamber 56 from an upstream region UA toward a downstream region DA of the axial fan 100J.

[0121] The axial fan 100J has the flow control portion 30. The flow control portion 30D is formed by one of the above-mentioned flow control portions 30, 30A, 30B, and 30C.

[0122] In the direction of the rotation axis RA, the rear edge 22 of the blade 20J is located more downstream, in the direction of the fluid flow created by rotation of the blade 20J, in a portion near the outer circumference in the radial direction than in a portion near the inner circumference in the radial direction. More specifically, the rear edge 22 has an outer-circumference-side end 22g that is located more downstream than is an inner-circumference-side end 22f of the rear edge 22 in the direction of the fluid flow created by rotation of the blade 20J. The outer-circumference-side end 22g is an end of the rear edge 22 located near the outer circumference in the radial direction. The outer-circumference-side end 22g is a portion of the outer circumferential edge 23 corresponding to the rear edge 22. The inner-circumference-side end 22f is an end of the rear edge 22 located near the inner circumference in the radial direction. The inner-circumference-side end 22f is a portion of the inner circumferential edge 24 corresponding to the rear edge 22.

[Operational Effects of Axial Fan 100J]

[0123] In the direction of the fluid flow created by rotation of the blade 20J, an outer circumferential region of the axial fan 100J in the radial direction is located more downstream than is an inner circumferential region of the axial fan 100J in the radial direction. This configuration of the axial fan 100J allows a fluid flow FL4 to be guided from an inner circumferential region of the blade 20J toward the flow control portion 30 located in an outer circumferential region where work is efficiently done on the fluid. This helps to reduce the required power consumption of the axial fan 100J. The above-mentioned configuration also allows for improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 100J. This leads to reduced noise generation.

Embodiment 11.

[Axial Fan 100K]

[0124] Fig. 19 is a conceptual diagram, as viewed from top, of the outdoor unit 50 including an axial fan 100K according to Embodiment 11. Reference is made below to Fig. 19 to describe the configuration of a blade 20K of the axial fan 100K in detail. Portions or parts of the axial fan 100K identical in configuration to those of the axial fan 100 or other axial fans illustrated in Figs. 1 to 18 are denoted by the same reference signs and not described below in further detail. For the axial fan 100K according to Embodiment 11, the location of the flow control portion 30 is further specified. As illustrated in Fig. 19, when the axial fan 100K activates, the fluid F flows in the air-sending chamber 56 from the upstream region UA toward the downstream region DA of the axial fan 100J.

[0125] The axial fan 100K has the flow control portion 30. The flow control portion 30D is formed by one of the above-mentioned flow control portions 30, 30A, 30B, and 30C.

[0126] The flow control portion 30 of the blade 20K is located between the midsection 29 and the rear edge 22. More specifically, the sectional portion S, which is a section perpendicular to the rotation axis RA and bent to have a concave part of the pressure surface 25 and a convex part of the suction surface 26, is located between the midsection 29 and the rear edge 22. As described above, the midsection 29 is located midway between the front edge 21 and the rear edge 22 in the direction of the rotation axis RA.

[0127] The flow control portion 30 of the blade 20K is formed between the midsection 29 and the rear edge 22 such that the projection amount L illustrated in Fig. 3 increases with increasing distance from the midsection 29 toward the rear edge 22. That is, the flow control portion 30 of the blade 20K is formed between the midsection 29 and the rear edge 22 such that bending of the blade 20 that is directed upstream increases with increasing distance from the midsection 29 toward the rear edge 22. In other words, the flow control portion 30 of the blade 20K is formed between the midsection 29 and the rear edge 22 such that the concave part of the pressure surface 25 increases in depth with increasing distance from the midsection 29 toward the rear edge 22. Therefore, in the flow control portion 30 of the blade 20K, the projection amount L2 is greater than the projection amount L1, and the projection amount L3 is greater than the projection amount L2. The flow control portion 30 of the blade 20K is formed between the midsection 29 and the rear edge 22 such that the projection amounts L1, L2, and L3 satisfy the following relationship: L1 < L2 < L3.

[Operational Effects of Axial Fan 100K]

[0128] The axial fan 100K is disposed in the outdoor unit 50 such that an upstream region of the axial fan 100K is open in the radial direction, and a downstream region of the axial fan 100K is surrounded by a bell mouth 63 and thus semi-open in the radial direction. The presence of the bell mouth 63 surrounding the downstream region of the axial fan 100K helps to reduce leakage of the fluid flow at the outer circumferential edge 23 of the blade 20. In the axial fan 100K, the flow control portion 30 is positioned downstream in the direction of fluid flow. This allows the flow control portion 30 to reduce leakage of the fluid flow more effectively. As a result, the required power consumption of the axial fan 100J is further reduced.

Embodiment 12.

[Refrigeration Cycle Apparatus 70]

[0129] Embodiment 12 is directed to using the axial fan 100 or other axial fans according to Embodiments 1 to 11 for the outdoor unit 50, which serves as an air-sending device of a refrigeration cycle apparatus 70.

[0130] Fig. 20 is a schematic diagram of the refrigeration cycle apparatus 70 according to Embodiment 12. Although the following description is directed to the refrigeration cycle apparatus 70 used for air-conditioning purposes, this is not intended to limit the use of the refrigeration cycle apparatus 70 to air conditioning. For example, the refrigeration cycle apparatus 70 is used for refrigeration or air-conditioning purposes, such as for refrigerators, freezers, vending machines, air-conditioning apparatuses, refrigeration apparatuses, and water heaters.

[0131] As illustrated in Fig. 20, the refrigeration cycle apparatus 70 includes a refrigerant circuit 71 formed by sequentially connecting the compressor 64, a condenser 72, an expansion valve 74, and an evaporator 73 by a refrigerant pipe. A condenser fan 72a, which sends air used for heat exchange to the condenser 72, is provided to the condenser 72. An evaporator fan 73a, which sends air used for heat exchange to the evaporator 73, is provided to the evaporator 73. At least one of the condenser fan 72a and the evaporator fan 73a is the axial fan 100 or other axial fans according to any one of Embodiments 1 to 10 mentioned above. In the refrigeration cycle apparatus 70, the refrigerant circuit 71 may be provided with a flow switching device such as a four-way valve that switches the flows of refrigerant to allow switching between heating operation and cooling operation.

[0132] Fig. 21 is a perspective view, as seen from near an air outlet, of the outdoor unit 50 serving as an air-sending device. Fig. 22 is a top view of the outdoor unit 50 for explaining the configuration of the outdoor unit 50. Fig. 23 illustrates the outdoor unit 50 with a fan grille removed from the outdoor unit 50. Fig. 24 illustrates the internal configuration of the outdoor unit 50 with the fan grille, a front panel, and other components removed from the outdoor unit 50.

[0133] As illustrated in Figs. 21 to 24, an outdoor unit body 51 serving as a casing is formed as an enclosure having the following surfaces: a lateral surface 51a and a lateral surface 51c, which define a pair of left and right lateral surfaces; a front surface 51b; a back surface 51d; a top surface 51e; and a bottom surface 51f. The lateral surface 51a and the back surface 51d each have an opening for sucking in air from the outside. The front surface 51b has an air outlet 53 formed in a front panel 52 to blow air to the outside. Further, the air outlet 53 is covered with a fan grille 54. This ensures safety by preventing contact between the axial fan 100 and, for example, an object located outside the outdoor unit body 51. Arrows AR in Fig. 22 each represent the flow of air.

[0134] The axial fan 100 and the fan motor 61 are accommodated in the outdoor unit body 51. The axial fan 100 is connected via a rotating shaft 62 to the fan motor 61, which is a drive source located near the back surface 51d. The axial fan 100 is driven to rotate by the fan motor 61. The fan motor 61 provides a drive force to the axial fan 100. The fan motor 61 is mounted to the motor support 69. The motor support 69 is disposed between the fan motor 61 and the heat exchanger 68.

[0135] The interior of the outdoor unit body 51 is divided by the partition plate 51g, which is a wall element, into the air-sending chamber 56 in which the axial fan 100 is installed, and the machine chamber 57 in which the compressor 64 and other components are installed. The heat exchanger 68, which extends in a substantially L-shape in plan view, is disposed at a location in the air-sending chamber 56 near the lateral surface 51a and the back surface 51d. The heat exchanger 68 acts as the evaporator 73 during heating operation, and acts as the condenser 72 during cooling operation.

[0136] The bell mouth 63 is disposed radially outward of the axial fan 100 disposed in the air-sending chamber 56. The bell mouth 63 surrounds an outer circumferential region of the axial fan 100, and serves to adjust the flow of gas created by the axial fan 100 or other components. The bell mouth 63 is located further outside than is the outer circumferential end of the blade 20, and defines an annular shape in the direction of rotation of the axial fan 100. The partition plate 51g is located beside one side of the bell mouth 63, and a portion of the heat exchanger 68 is located beside the other side of the bell mouth 63.

[0137] The front end of the bell mouth 63 is connected to the front panel 52 of the outdoor unit 50 to surround the periphery of the air outlet 53. The bell mouth 63 may be integral with the front panel 52, or may be provided as a separate component to be connected to the front panel 52. Because of the presence of the bell mouth 63, the passage between the inlet side and the outlet side of the bell mouth 63 is defined as an air passageway near the air outlet 53. That is, the air passageway near the air outlet 53 is partitioned off by the bell mouth 63 from other spaces in the air-sending chamber 56.

[0138] The heat exchanger 68 disposed near the air inlet of the axial fan 100 includes multiple fins with plate-like surfaces arranged side by side in parallel to each other, and heat transfer tubes penetrating the fins in a direction in which the fins are arranged side by side. Refrigerant that circulates in the refrigerant circuit flows in the heat transfer tubes. In the heat exchanger 68 according to Embodiment 12, multiple rows of heat transfer tubes extend in an L-shape over the lateral surface 51a and the back surface 51d of the outdoor unit body 51, and follow a meandering path while penetrating the fins.

The heat exchanger 68 is connected to the compressor 64 via a pipe 65 or other components, and is further connected to an indoor-side heat exchanger (not illustrated), the expansion valve, and other components to form the refrigerant circuit 71 of the air-conditioning apparatus. A board case 66 is disposed in the machine chamber 57. A control board 67 disposed in the board case 66 controls devices mounted in the outdoor unit.

[Operational Effects of Refrigeration Cycle Apparatus 70 and Air-sending Device]

[0139] Embodiment 10 provides advantages similar to Embodiments 1 to 9 corresponding to Embodiment 10. For example, the above-mentioned configuration of the axial fan 100 helps to reduce leakage of the fluid from the pressure surface 25 at the outer circumferential end of the blade 20, and consequently reduce growth of a blade tip vortex. The above-mentioned configuration also helps to reduce the required power consumption of the axial fan 100. This consequently makes it possible to reduce the required power consumption of the refrigeration cycle apparatus 70, and the required power consumption of the outdoor unit 50, which is an air-sending device. The above-mentioned configuration also allows for improved radial uniformity of the velocity distribution of the fluid blown by the axial fan 100. This leads to reduced noise generation. This consequently makes it possible to reduce noise generated by the refrigeration cycle apparatus 70, and noise generated by the outdoor unit 50, which is an air-sending device.

[0140] The configurations described in the foregoing description of the embodiments are intended to be illustrative only. These configurations may be combined with other known techniques, or may be partially omitted or changed without departing from the scope of the present disclosure.

Reference Signs List

[0141] 10: hub, 10p: hub projected portion, 20: blade, 20A: blade, 20B: blade, 20C: blade, 20D: blade, 20E: blade, 20F: blade, 20G: blade, 20H: blade, 20I: blade, 20J: blade, 20K: blade, 20L: blade, 20R: blade, 20p: blade projected portion, 20q: blade projected portion, 21: front edge, 21p: front-edge projection line, 22: rear edge, 22a: projection, 22b: outer-circumference-side rear edge, 22f: inner-circumference-side end, 22g: outer-circumference-side end, 22p: rear-edge projection line, 23: outer circumferential edge, 23p: outer-edge projection line, 24: inner circumferential edge, 24p: inner-edge projection line, 25: pressure surface, 26: suction surface, 27: blade length, 28: virtual blade intermediate line, 29: midsection, 30: flow control portion, 30A: flow control portion, 30B: flow control portion, 30C: flow control portion, 30D: flow control portion, 30L: flow control portion, 30R: flow control portion, 31: regional inner edge, 32: regional outer edge, 33: virtual regional intermediate line, 35: deepest part, 35a: deepest part, 35b: deepest part, 35c: deepest part, 40: inner-circumference-side flow control portion, 40G: inner-circumference-side flow control portion, 40H: inner-circumference-side flow control portion, 40I: inner-circumference-side flow control portion, 41: inner-circumference-side regional inner edge, 42: inner-circumference-side regional outer edge, 43: inner-circumference-side virtual regional intermediate line, 45: inner-circumference-side deepest part, 45a: inner-circumference-side deepest part, 45b: inner-circumference-side deepest part, 45c: inner-circumference-side deepest part, 50: outdoor unit, 50L: outdoor unit, 51: outdoor unit body, 51a: lateral surface, 51b: front surface, 51c: lateral surface, 51d: back surface, 51e: top surface, 51f: bottom surface, 51g: partition plate, 52: front panel, 53: air outlet, 54: fan grill, 56: air-sending chamber, 57: machine chamber, 61: fan motor, 62: rotating shaft, 63: bell mouth, 64: compressor, 65: pipe, 66: board case, 67: control board, 68: heat exchanger, 69: motor support, 70: refrigeration cycle apparatus, 71: refrigerant circuit, 72: condenser, 72a: condenser fan, 73: evaporator, 73a: evaporator fan, 74: expansion valve, 100: axial fan, 100A: axial fan, 100B: axial fan, 100C: axial fan, 100D: axial fan, 100E: axial fan, 100F: axial fan, 100G: axial fan, 100H: axial fan, 1001: axial fan, 100J: axial fan, 100K: axial fan, 100L: axial fan, 100R: axial fan, AD: axial direction, AF: direction, AR: arrow, CD: circumferential direction, DA: downstream region, DR: rotation direction, F: fluid, FL: airflow, L: projection amount, L1: projection amount, L2: projection amount, L3: projection amount, LI: inner-circumference-side projection amount, LI1: inner-circumference-side projection amount, LI2: inner-circumference-side projection amount, LI3: inner-circumference-side projection amount, MA: maximum air velocity region, ML: maximum air velocity region, R1: distance, R2: distance, R3: distance, RI1: distance, RI2: distance, RI3: distance, RA: rotation axis, S: sectional portion, S1: sectional portion, S2: sectional portion, S3: sectional portion, SI: inner-circumference-side sectional portion, S11: inner-circumference-side sectional portion, SI2: inner-circumference-side sectional portion, SI3: inner-circumference-side sectional portion, SL: sectional portion, SL1: sectional portion, SL2: sectional portion, SL3: sectional portion, SR: sectional portion, SR1: sectional portion, SR2: sectional portion, SR3: sectional portion, UA: upstream region, VP: viewpoint, W: sectional straight line, W1: sectional straight line, W1a: inner-circumference-side end, W1b: outer-circumference-side end, W1d: inner-circumference-side end, W1e: outer-circumference-side end, W2: sectional straight line, W2a: inner-circumference-side end, W2b: outer-circumference-side end, W2d: inner-circumference-side end, W2e: outer-circumference-side end, W3: sectional straight line, W3a: inner-circumference-side end, W3b: outer-circumference-side end, W3d: inner-circumference-side end, W3e: outer-circumference-side end, WI: inner-circumference-side straight line, WI1: inner-circumference-side straight line, WI2: inner-circumference-side straight line, WI3: inner-circumference-side straight line, Φ: angle, Φ1: angle, Φ2: angle, Φ3: angle, θ: angle, θ1: angle, θ2: angle, θ3: angle

Claims

1. An axial fan, comprising:

a hub having a rotation axis and configured to be driven to rotate; and
a blade connected to the hub and having a front edge and a rear edge,
the blade having a flow control portion that is located in at least part of a portion between the front edge and the rear edge and that guides a flow of a fluid on a pressure surface of the blade, the flow control portion having
a regional inner edge,
a regional outer edge located closer to an outer circumference of the axial fan than is the regional inner edge, the regional inner edge being located closer to an inner circumference of the axial fan than is the regional outer edge, and
a sectional portion being a section that is located between the regional inner edge and the regional outer edge and is perpendicular to the rotation axis, the sectional portion being bent to have a concave part of the pressure surface,
in the flow control portion, a virtual regional intermediate line extending through a middle of a region between the regional inner edge and the regional outer edge in a radial direction, the virtual regional intermediate line being located closer to the outer circumference than is a virtual blade intermediate line that extends through a middle of the blade in the radial direction,
where, in the sectional portion, a distance to a portion of the pressure surface that is farthest in a normal direction from a sectional straight line that is a straight line connecting the regional inner edge and the regional outer edge is defined as a projection amount,
the projection amount increasing with increasing distance from the front edge toward the rear edge.

2. The axial fan of claim 1,

wherein the flow control portion has a deepest part, the deepest part being a part of the sectional portion where the pressure surface is most concave, and
wherein, with increasing distance from the front edge toward the rear edge, the deepest part is positioned further toward an outer circumferential edge of the blade from a location near the inner circumference in the radial direction.

3. The axial fan of claim 1 or 2,

wherein an intersection of the sectional straight line and the regional inner edge is defined as a first inner-circumference-side end,
wherein an intersection of the sectional straight line and the regional outer edge is defined as a first outer-circumference-side end,
wherein a straight line passing the rotation axis and the first inner-circumference-side end is defined as a first straight line,
wherein a straight line passing the rotation axis and the first outer-circumference-side end is defined as a second straight line,
wherein an angle between the first straight line and the second straight line is defined as an angle θ, and
wherein the angle θ is greater near the rear edge than near the front edge.

4. The axial fan of claim 1 or 2,

wherein an intersection of the sectional straight line and the regional inner edge is defined as a first inner-circumference-side end,
wherein an intersection of the sectional straight line and the regional outer edge is defined as a first outer-circumference-side end,
wherein a straight line passing the rotation axis and the first inner-circumference-side end is defined as a first straight line,
wherein a straight line passing the rotation axis and the first outer-circumference-side end is defined as a second straight line,
wherein an angle between the first straight line and the second straight line is defined as an angle θ, and
wherein the angle θ is less near the rear edge than near the front edge.

5. The axial fan of any one of claims 1 to 4,

wherein the rear edge has
an outer-circumference-side rear edge defining a rear edge near an outer circumference of the blade, and
a projecting part defining a rear edge that is located closer to an inner circumference of the blade than is the outer-circumference-side rear edge, the projecting part projecting further toward a trailing portion of the blade in a direction of rotation of the blade than is the outer-circumference-side rear edge.

6. The axial fan of claim 5,

wherein the blade further has
an inner-circumference-side flow control portion

located between a midsection and the rear edge, the midsection being a portion of the blade located midway between the front edge and the rear edge, the inner-circumference-side flow control portion being positioned in the radial direction to at least partially overlap a region where the projecting part is provided, the inner-circumference-side flow control portion guiding the flow of the fluid on a portion of the pressure surface that is near the inner circumference of the blade,

wherein the inner-circumference-side flow control portion has

an inner-circumference-side regional inner edge,

an inner-circumference-side regional outer edge located closer to the outer circumference than is the inner-circumference-side regional inner edge, the inner-circumference-side regional inner edge being located closer to the inner circumference than is the inner-circumference-side regional outer edge, and

an inner-circumference-side sectional portion being a section that is located between the inner-circumference-side regional inner edge and the inner-circumference-side regional outer edge and is perpendicular to the rotation axis, the inner-circumference-side sectional portion being bent to have a concave part of the pressure surface,

wherein, in the inner-circumference-side flow control portion, an inner-circumference-side virtual regional intermediate line extends through a middle of a region between the inner-circumference-side regional inner edge and the inner-circumference-side regional outer edge, the inner-circumference-side virtual regional intermediate line being located closer to the inner circumference than is the virtual blade intermediate line in the radial direction,

wherein, in the inner-circumference-side sectional portion, a distance to a portion of the pressure surface that is farthest in a normal direction from an inner-circumference-side straight line that is a straight line connecting the inner-circumference-side regional inner edge and the inner-circumference-side regional outer edge is defined as an inner-circumference-side projection amount, and

wherein the blade has a region where the inner-circumference-side projection amount is constant with increasing distance from the front edge toward the rear edge, or a region where the inner-circumference-side projection amount decreases with increasing distance from the front edge toward the rear edge.

7. The axial fan of claim 5,

wherein the blade further has

an inner-circumference-side flow control portion located between a midsection and the rear edge, the midsection being a portion of the blade located midway between the front edge and the rear edge, the inner-circumference-side flow control portion being positioned in the radial direction to at least partially overlap a region where the projecting part is provided, the inner-circumference-side flow control portion guiding the flow of the fluid on a portion of the pressure surface that is near the inner circumference of the blade,

wherein the inner-circumference-side flow control portion has

an inner-circumference-side regional inner edge,

an inner-circumference-side regional outer edge located closer to the outer circumference than is the inner-circumference-side regional inner edge, the inner-circumference-side regional inner edge being located closer to the inner circumference than is the inner-circumference-side regional outer edge, and

an inner-circumference-side sectional portion being a section that is located between the inner-circumference-side regional inner edge and the inner-circumference-side regional outer edge and is perpendicular to the rotation axis, the inner-circumference-side sectional portion being bent to have a concave part of the pressure surface,

wherein, in the inner-circumference-side flow control portion, an inner-circumference-side virtual regional intermediate line extends through a middle of a region between the inner-circumference-side regional inner edge and the inner-circumference-side regional outer edge, the inner-circumference-side virtual regional intermediate line being located closer to the inner circumference than is the virtual blade intermediate line in the radial direction,

wherein, in the inner-circumference-side sectional portion, a distance to a portion of the pressure surface that is farthest in a normal direction from an inner-circumference-side straight line that is a straight line connecting the inner-circumference-side regional inner edge and the inner-circumference-side regional outer edge is defined as an inner-circumference-side projection amount, and

wherein the inner-circumference-side projection amount increases with increasing distance from the front edge toward the rear edge.

8. The axial fan of claim 6 or 7,

wherein the inner-circumference-side flow con-

trol portion has an inner-circumference-side deepest part, the inner-circumference-side deepest part being a part of the inner-circumference-side sectional portion where the pressure surface is most concave, and
wherein, with increasing distance from the front edge toward the rear edge, the inner-circumference-side deepest part is positioned further toward the inner circumference from a location near the outer circumference in the radial direction.

9. The axial fan of any one of claims 6 to 8,

wherein an intersection of the inner-circumference-side straight line and the inner-circumference-side regional inner edge is defined as a second inner-circumference-side end,
wherein an intersection of the inner-circumference-side straight line and the inner-circumference-side regional outer edge is defined as a second outer-circumference-side end,
wherein a straight line passing the rotation axis and the second inner-circumference-side end is defined as a first inner-circumference-side straight line,
wherein a straight line passing the rotation axis and the second outer-circumference-side end is defined as a second inner-circumference-side straight line,
wherein an angle between the first inner-circumference-side straight line and the second inner-circumference-side straight line is defined as an angle Φ, and
wherein the angle Φ is greater near the rear edge than near the front edge.

10. The axial fan of any one of claims 1 to 9,
wherein, in a direction of the rotation axis, the rear edge is located more downstream, in a direction of fluid flow created by rotation of the blade, in a portion near the outer circumference in the radial direction than in a portion near the inner circumference in the radial direction.

11. The axial fan of any one of claims 1 to 5,
wherein the flow control portion is located between a midsection and the rear edge, the midsection being located midway between the front edge and the rear edge.

12. The axial fan of any one of claims 6 to 9,
wherein the flow control portion is located between the midsection and the rear edge.

13. An air-sending device, comprising:

the axial fan of any one of claims 1 to 12;
a drive source configured to provide a drive force to the axial fan; and
a casing accommodating the axial fan and the drive source.

14. A refrigeration cycle apparatus, comprising:

the air-sending device of claim 13; and
a refrigerant circuit having a condenser and an evaporator,
the air-sending device being configured to send air to at least one of the condenser and the evaporator.

FIG. 1

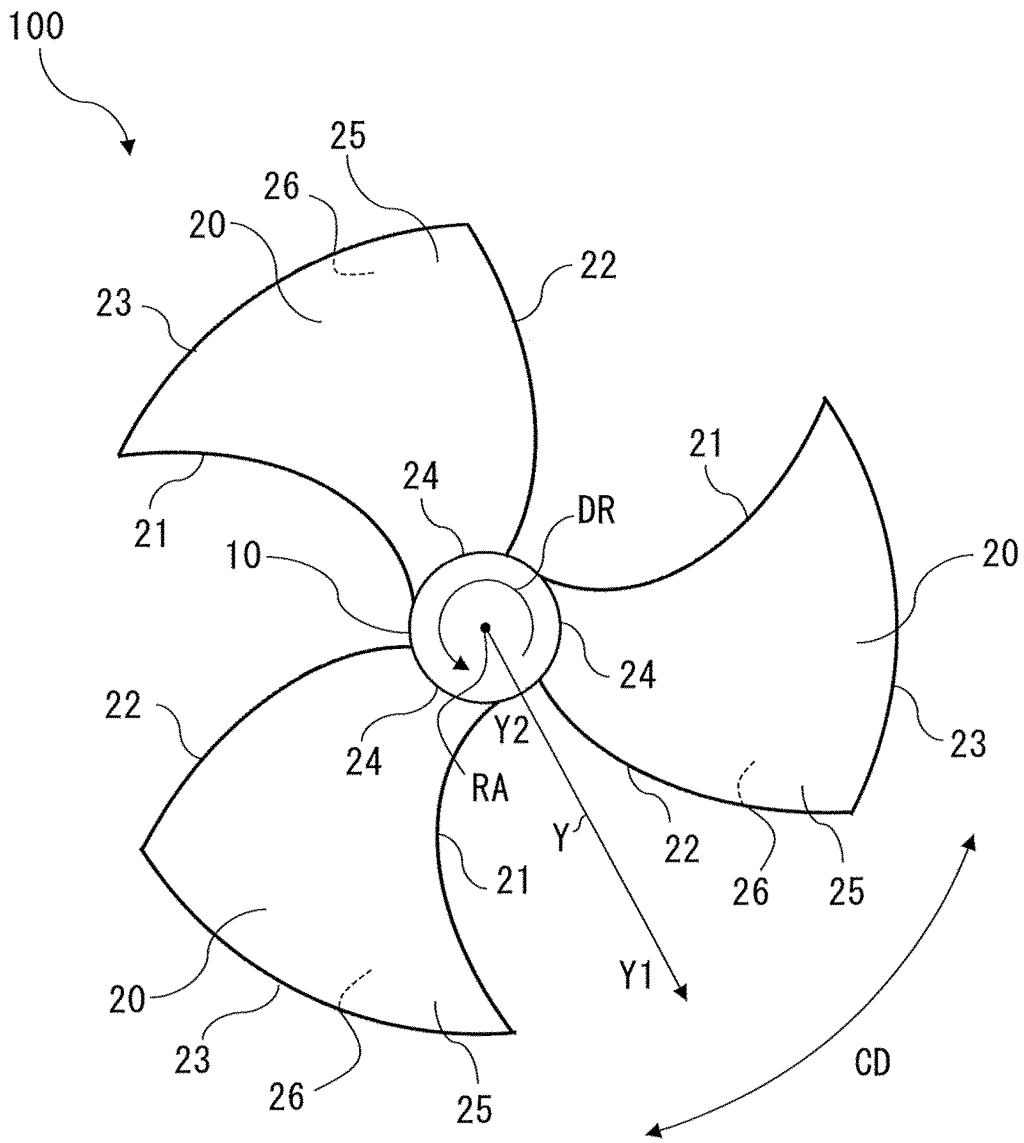

100
25
26
20
22
23
21
24
DR
21
10
20
24
22
23
24
Y2
RA
Y
22
26
25
21
Y1
20
23
26
25
CD

FIG. 2

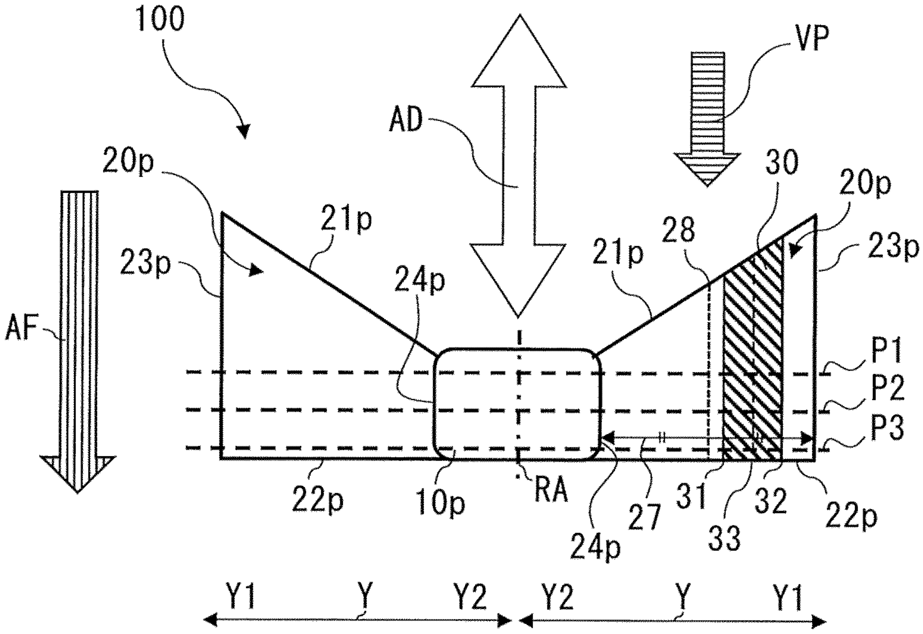

100
AD
VP
20p
30
20p
21p
28
21p
23p
23p
24p
AF
P1
P2
P3
22p
10p
RA
31
32
22p
27
33
24p
Y1
Y
Y2
Y2
Y
Y1

FIG. 3

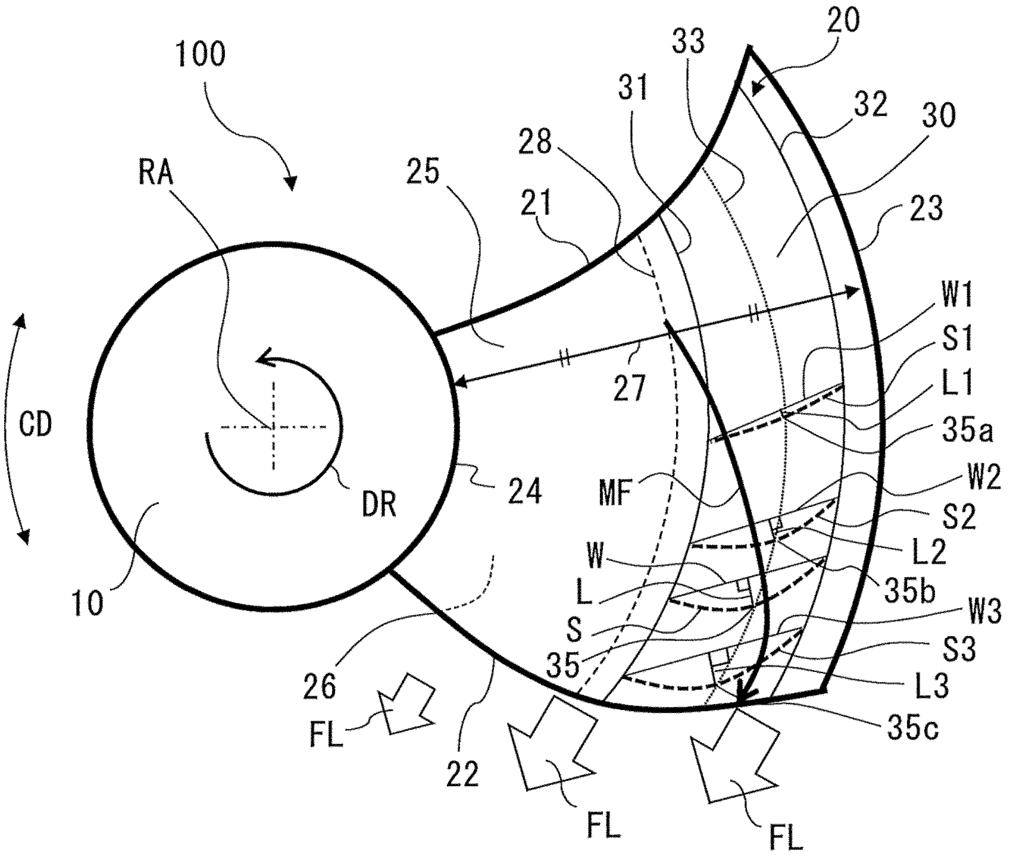

100
20
33
31
32
30
RA
28
25
21
23
W1
S1
27
L1
CD
35a
DR
24
MF
W2
S2
10
W
L2
L
35b
S
W3
35
S3
26
L3
35c
FL
22
FL
FL

FIG. 4

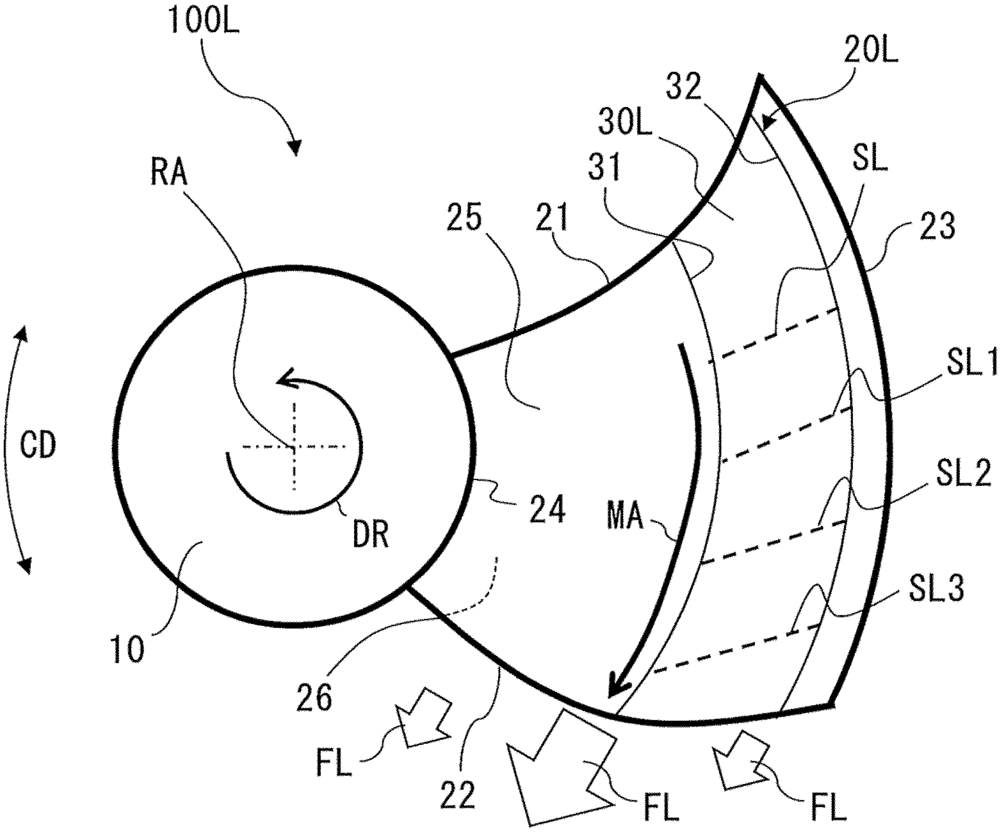

100L
20L
32
30L
31
SL
RA
25
21
23
SL1
CD
24
SL2
MA
DR
SL3
10
26
FL
22
FL
FL

FIG. 5

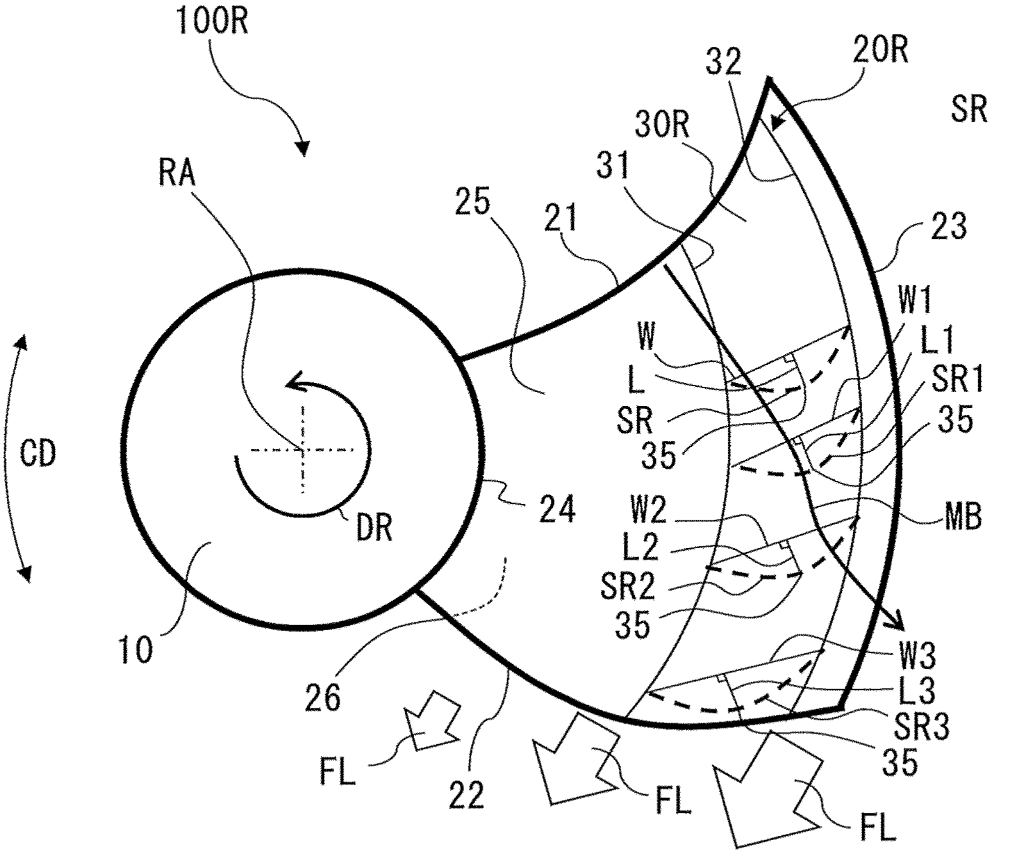

100R
32
20R
SR
30R
31
RA
25
21
23
W1
W
L1
L
SR1
SR
35
35
CD
MB
24
DR
W2
L2
SR2
35
10
W3
L3
26
SR3
35
FL
22
FL
FL

FIG. 6

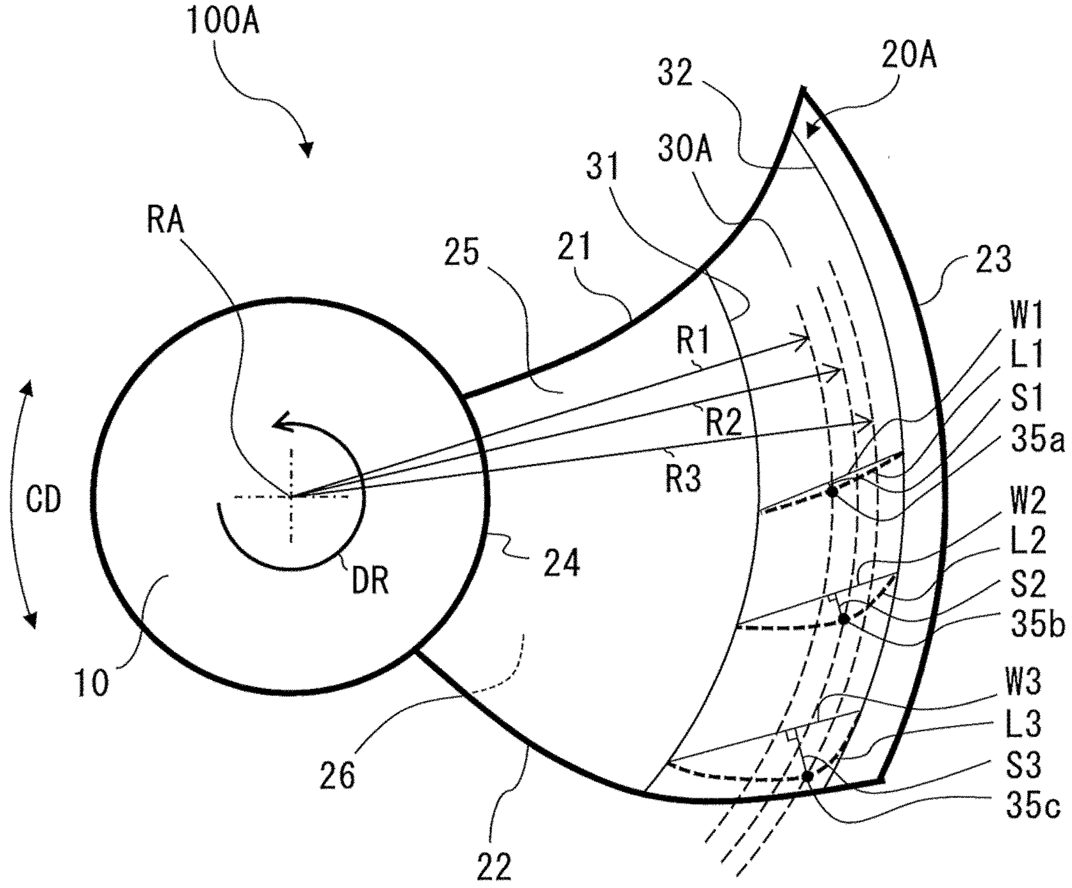

100A
20A
32
30A
31
RA
25
21
23
R1
W1
L1
R2
S1
35a
R3
CD
W2
24
L2
DR
S2
35b
10
W3
L3
26
S3
35c
22

FIG. 7

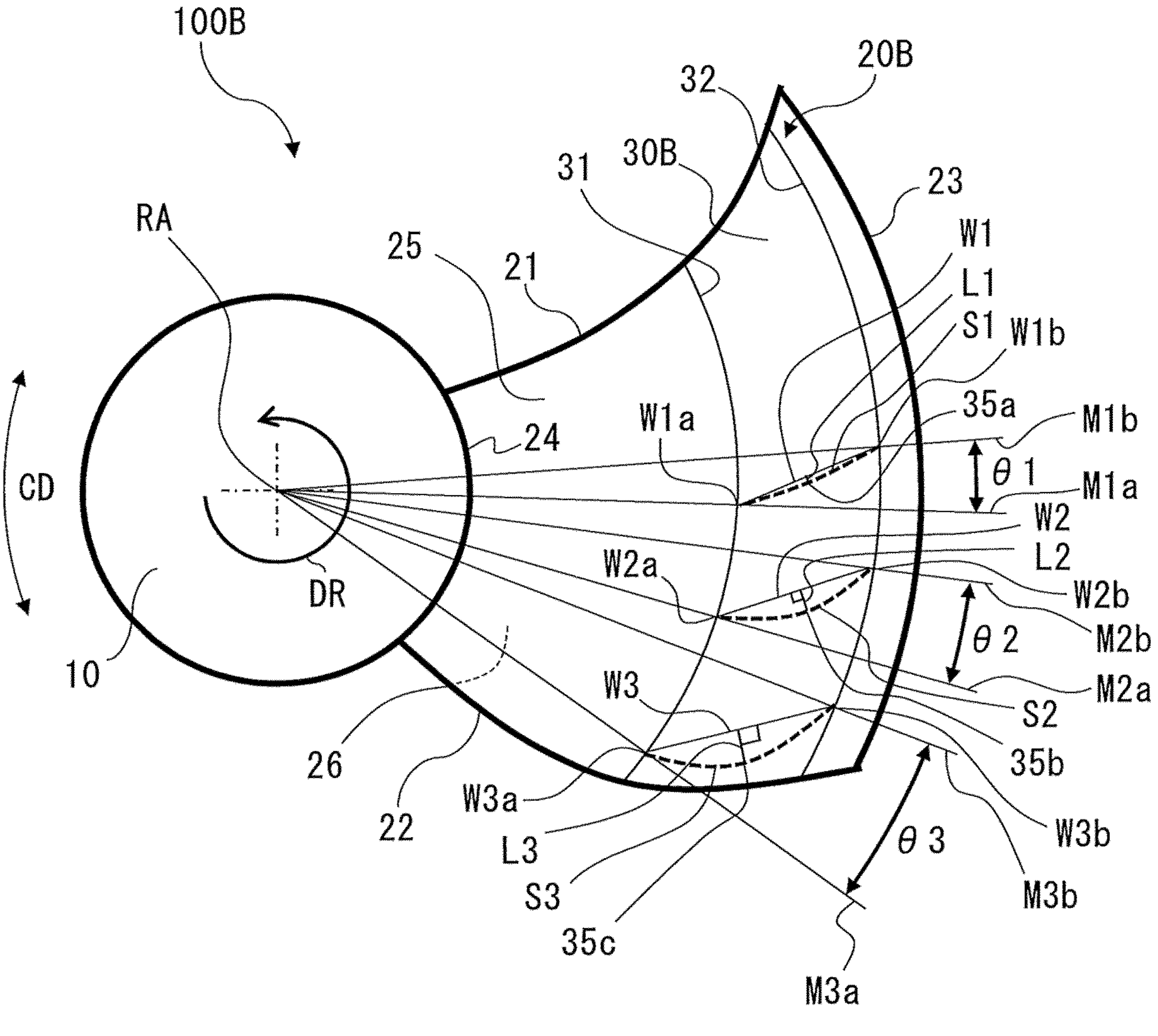

100B
20B
32
30B
31
23
RA
25
21
W1
L1
S1
W1b
35a
W1a
M1b
24
CD
θ 1
M1a
W2
L2
W2a
W2b
DR
M2b
θ 2
10
M2a
W3
S2
26
35b
W3a
22
W3b
θ 3
L3
S3
M3b
35c
M3a

FIG. 8

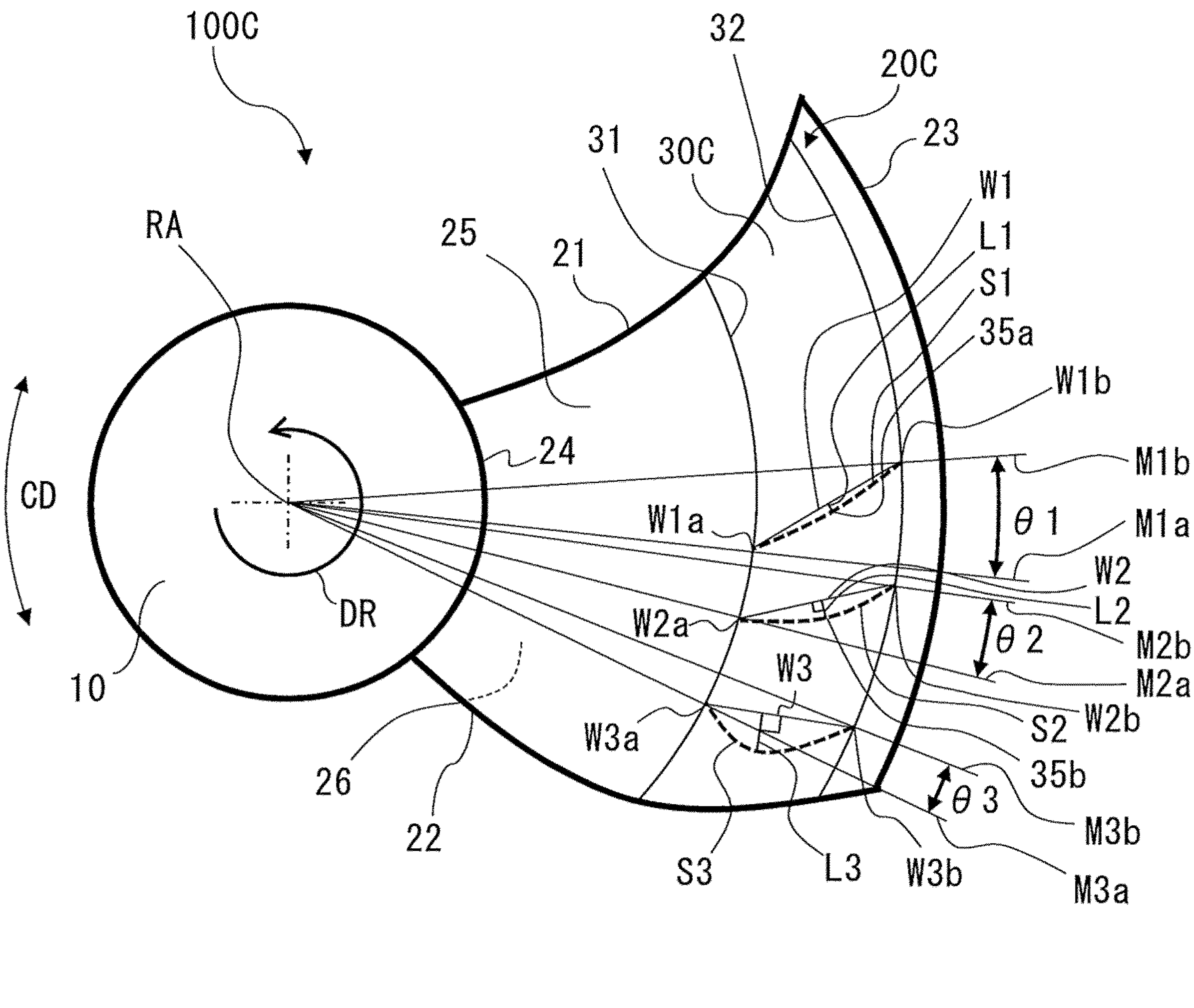

100C
32
20C
23
31
30C
W1
L1
S1
35a
W1b
RA
25
21
24
CD
M1b
θ 1
W1a
M1a
W2
L2
M2b
W2a
θ 2
DR
M2a
W3
10
W2b
W3a
S2
35b
26
θ 3
22
M3b
S3
L3
W3b
M3a

FIG. 9

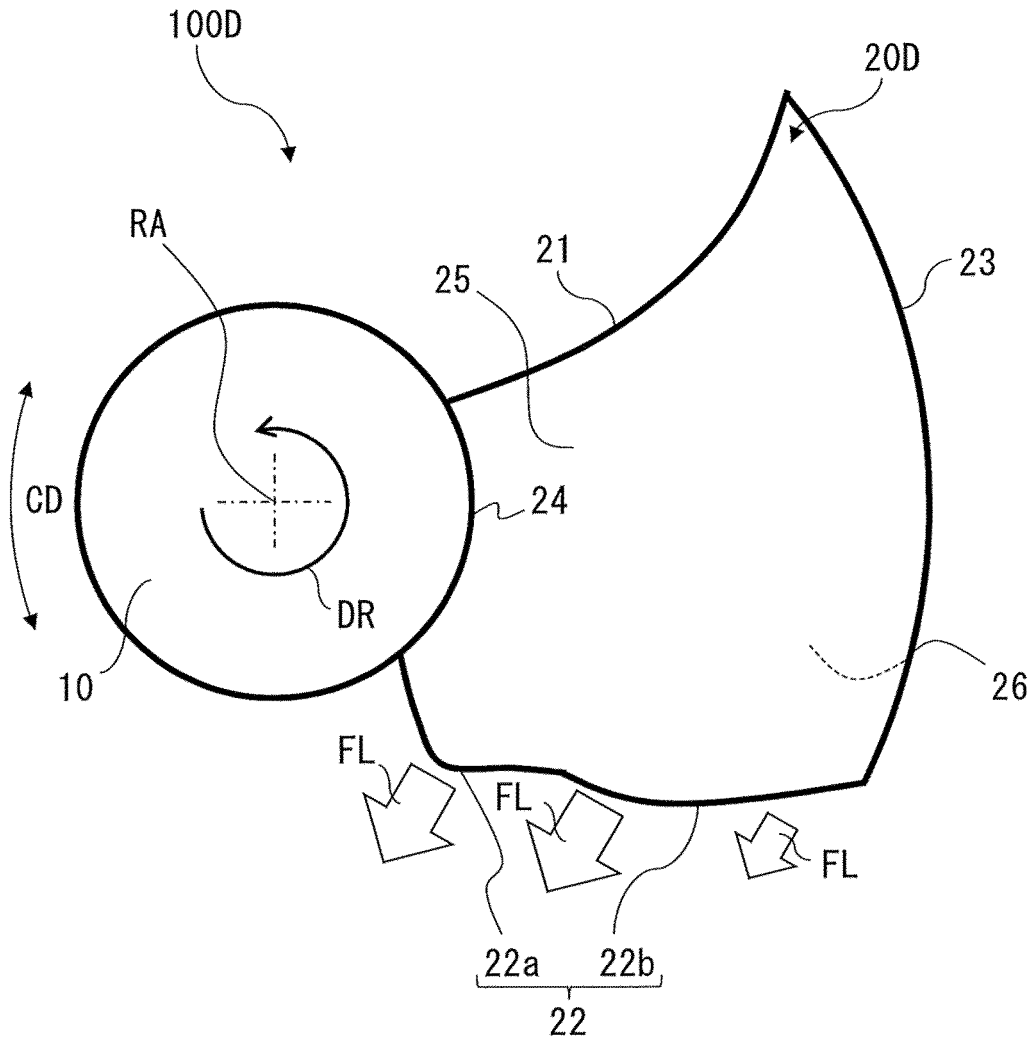


FIG. 10

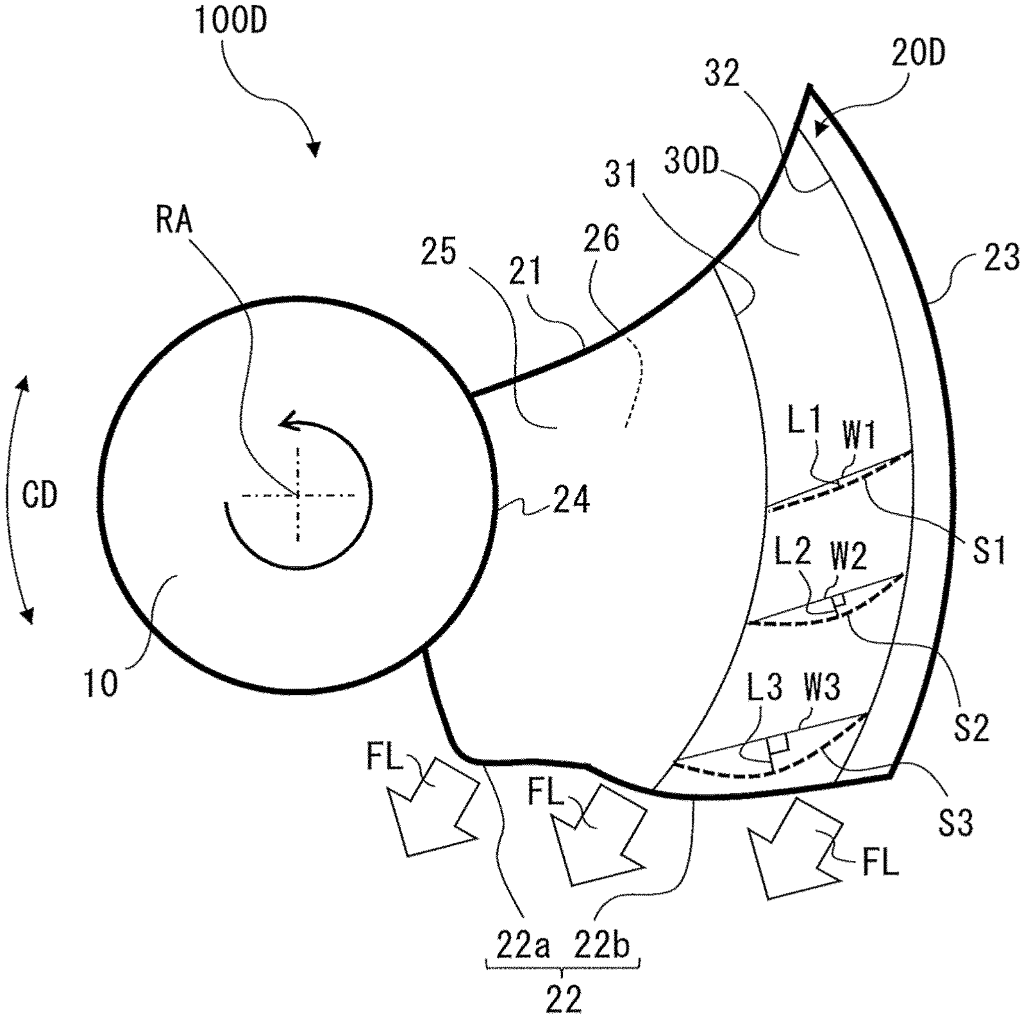
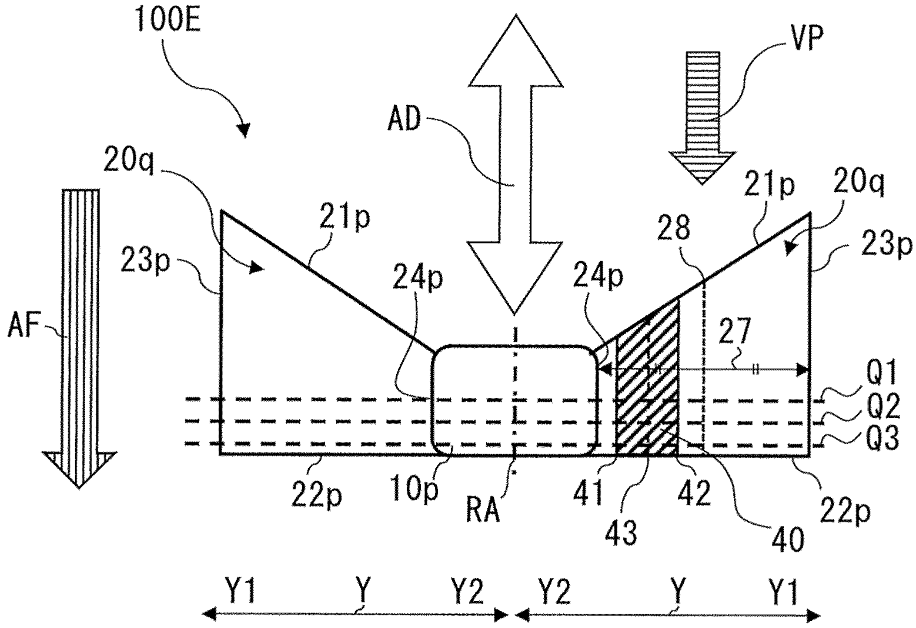
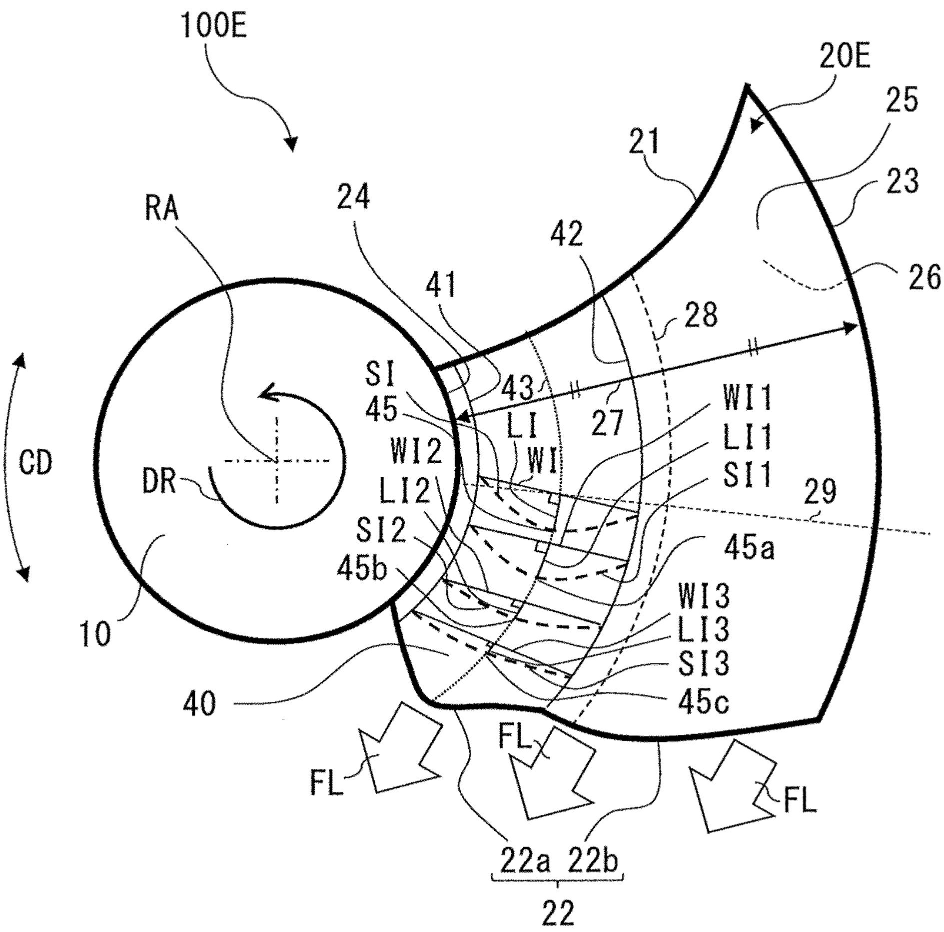

100D
20D
32
31
30D
RA
25
21
26
23
CD
24
L1
W1
S1
L2
W2
S2
10
L3
W3
S3
FL
FL
FL
22a
22b
22

FIG. 11



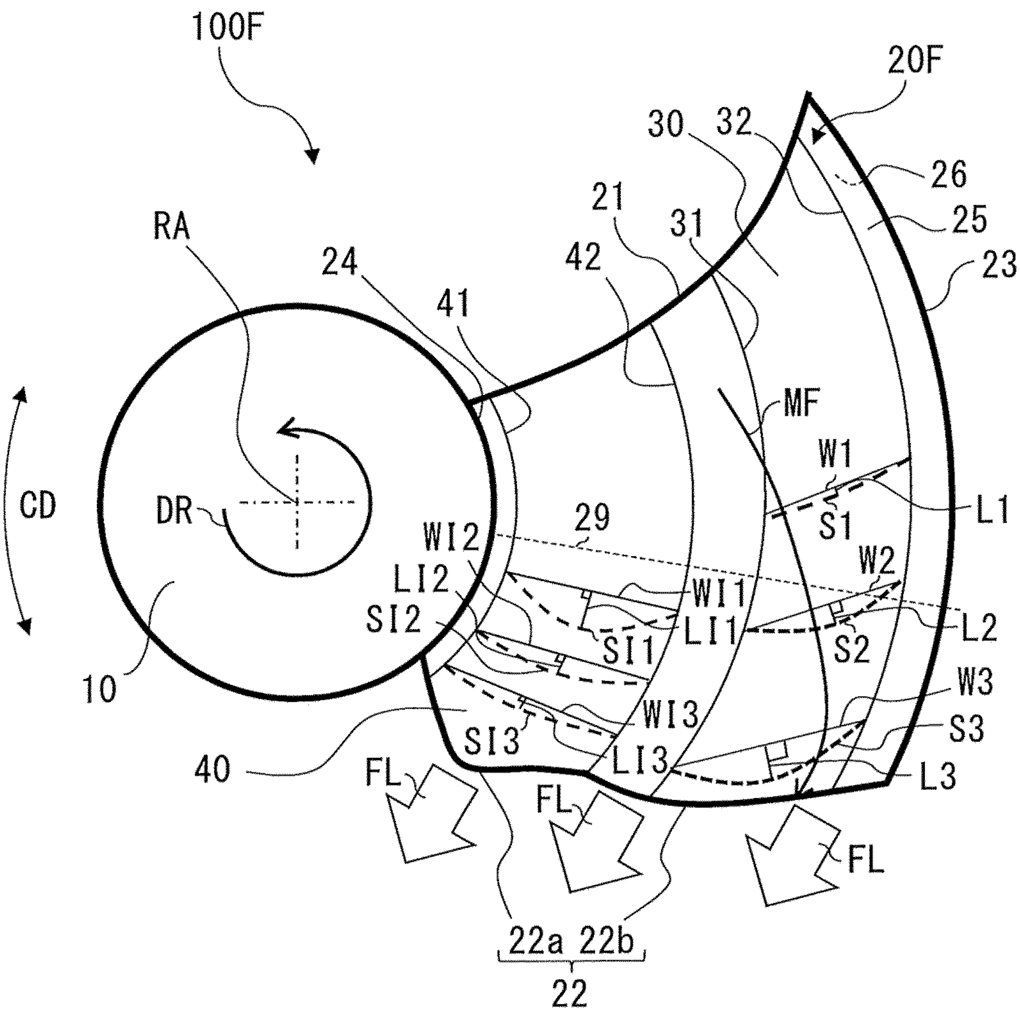
100E
VP
AD
20q
21p
20q
21p
28
23p
23p
24p
24p
AF
27
Q1
Q2
Q3
22p
10p
RA
41
43
42
40
22p
Y1
Y
Y2
Y2
Y
Y1

FIG. 12



100E
20E
25
21
23
RA
24
42
26
41
28
SI
45
43
LI
27
WI1
LI1
SI1
CD
WI2
WI
DR
LI2
29
SI2
45a
45b
10
WI3
LI3
SI3
40
45c
FL
FL
FL
22a
22b
22

FIG. 13



100F
20F
30
32
26
21
31
25
RA
24
42
23
41
MF
W1
CD
DR
L1
S1
29
WI2
W2
LI2
WI1
SI2
LI1
L2
S2
SI1
W3
10
WI3
S3
SI3
40
LI3
L3
FL
FL
FL
22a
22b
22

FIG. 14

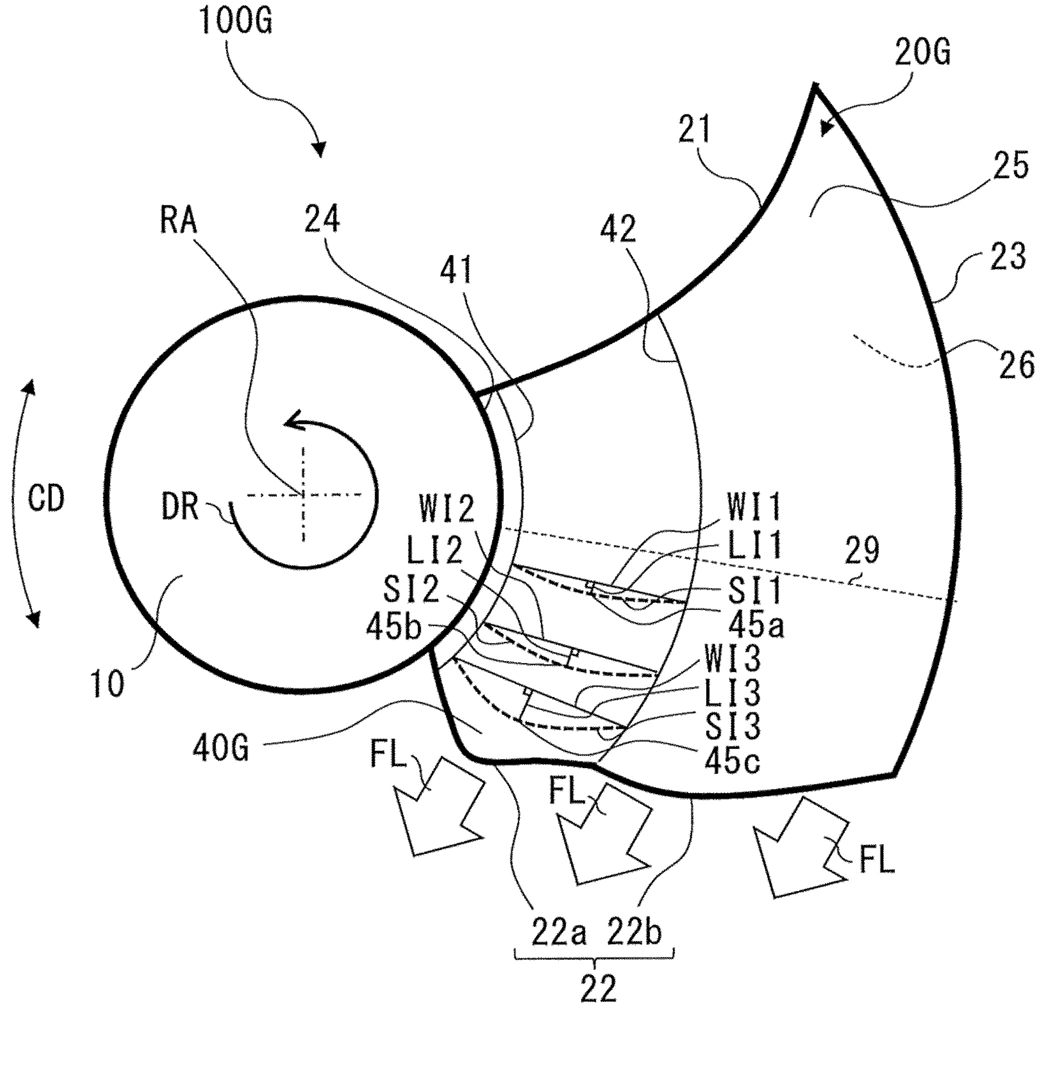

100G
20G
21
25
RA
24
42
41
23
26
CD
DR
WI2
WI1
LI1
29
LI2
SI2
SI1
45b
45a
WI3
10
LI3
SI3
40G
45c
FL
FL
FL
22a
22b
22

FIG. 15

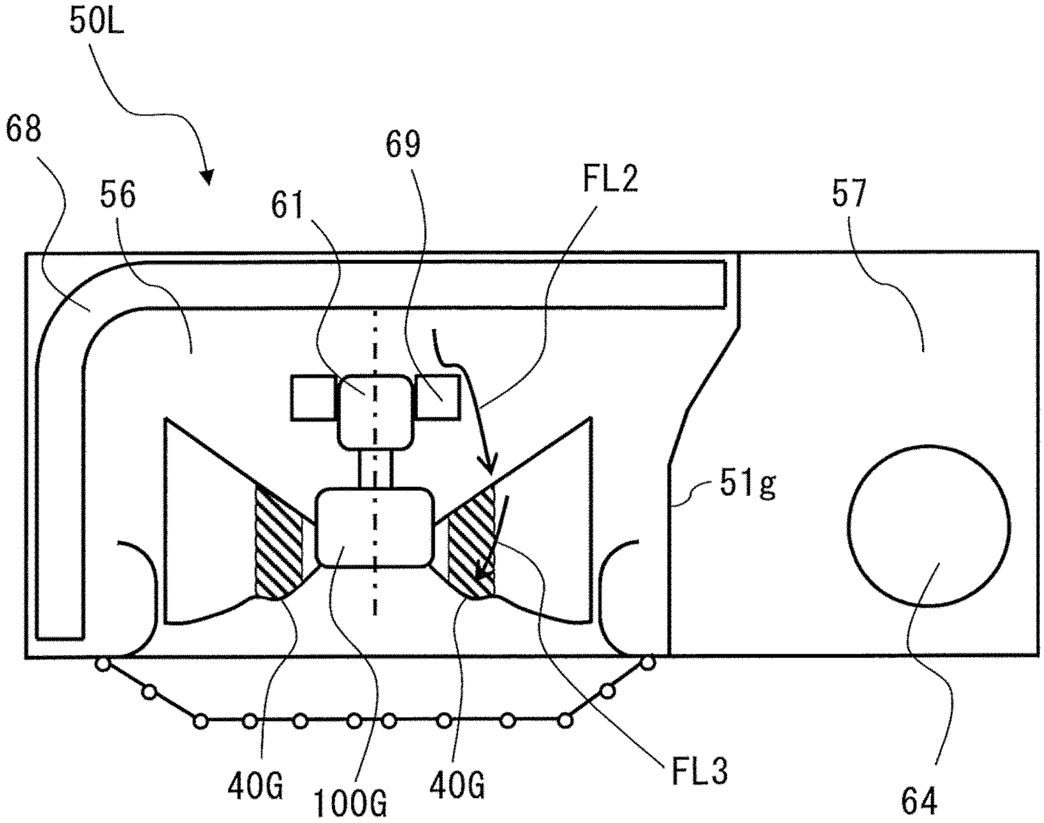


FIG. 16

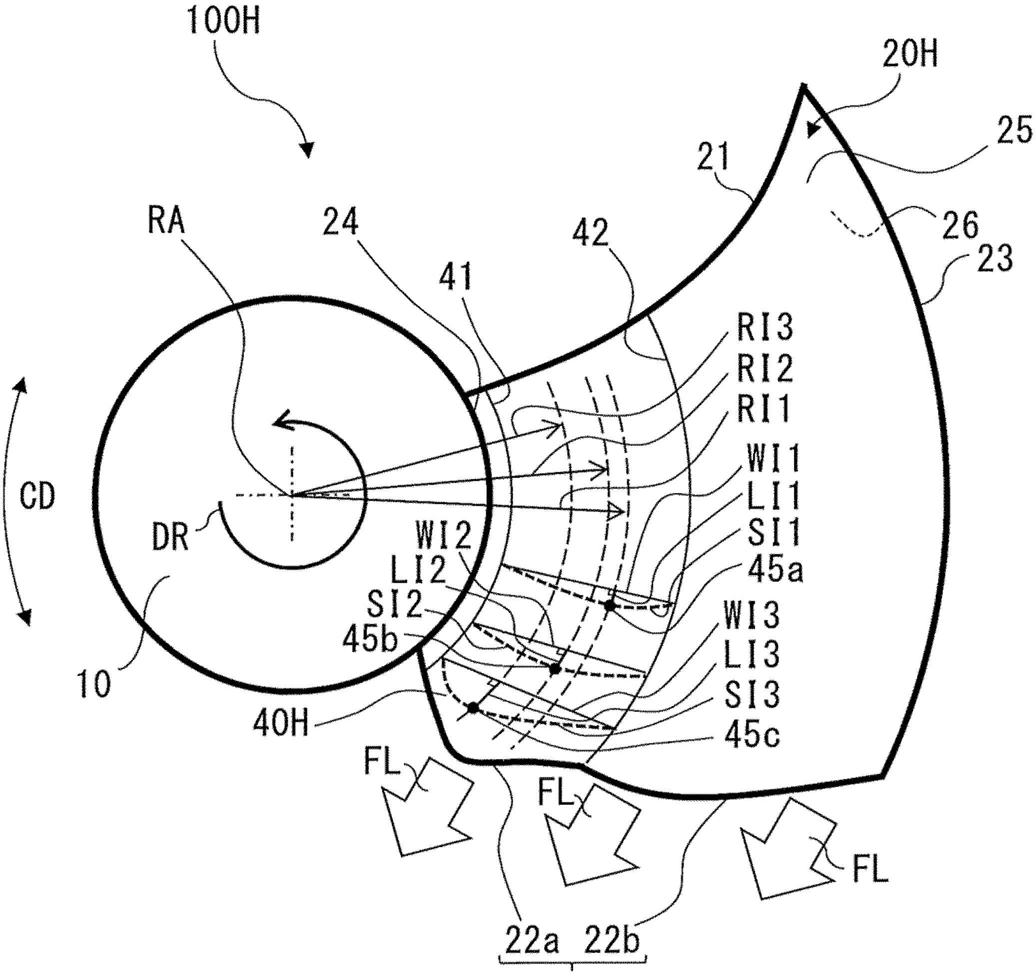

100H
20H
25
21
RA
24
42
26
23
41
RI3
RI2
RI1
WI1
LI1
SI1
45a
CD
DR
WI2
LI2
SI2
45b
WI3
LI3
SI3
45c
10
40H
FL
FL
FL
22a
22b
22

FIG. 17

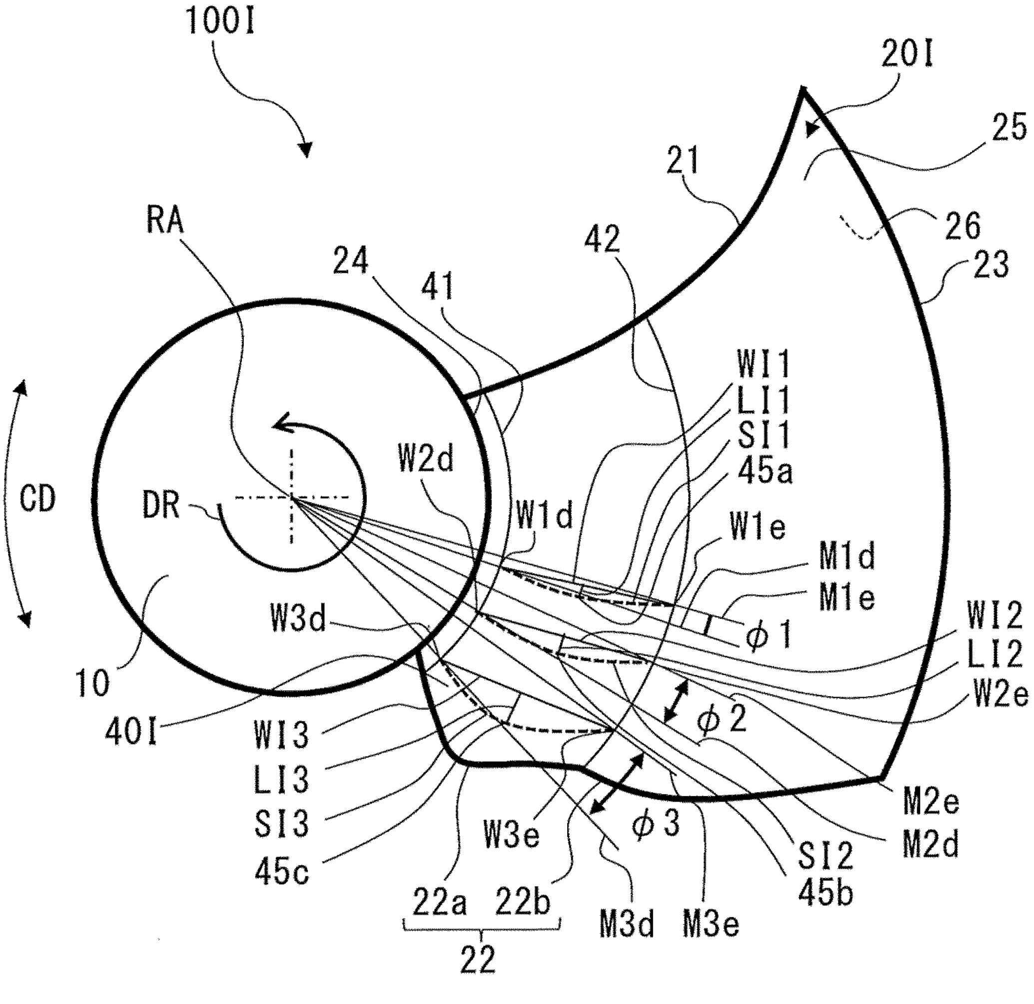

100I
20I
25
21
26
23
42
RA
24
41
WI1
LI1
SI1
45a
W2d
W1d
W1e
CD
DR
M1d
M1e
φ1
W3d
WI2
LI2
W2e
10
40I
φ2
WI3
LI3
SI3
45c
M2e
φ3
W3e
SI2
M2d
45b
22a
22b
M3d
M3e
22

FIG. 18

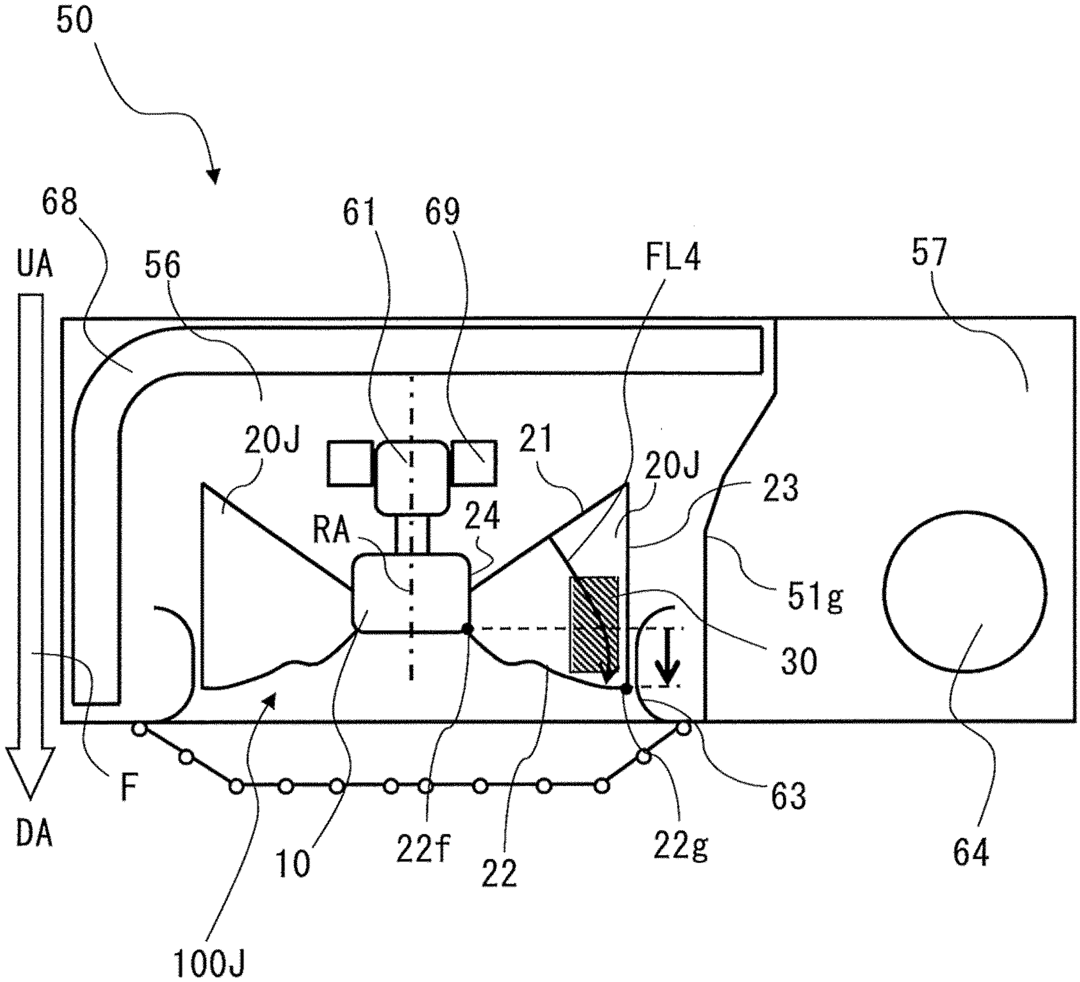

50
68
UA
56
61
69
FL4
57
20J
21
20J
23
RA
24
51g
30
F
DA
10
22f
22
22g
63
64
100J

FIG. 19

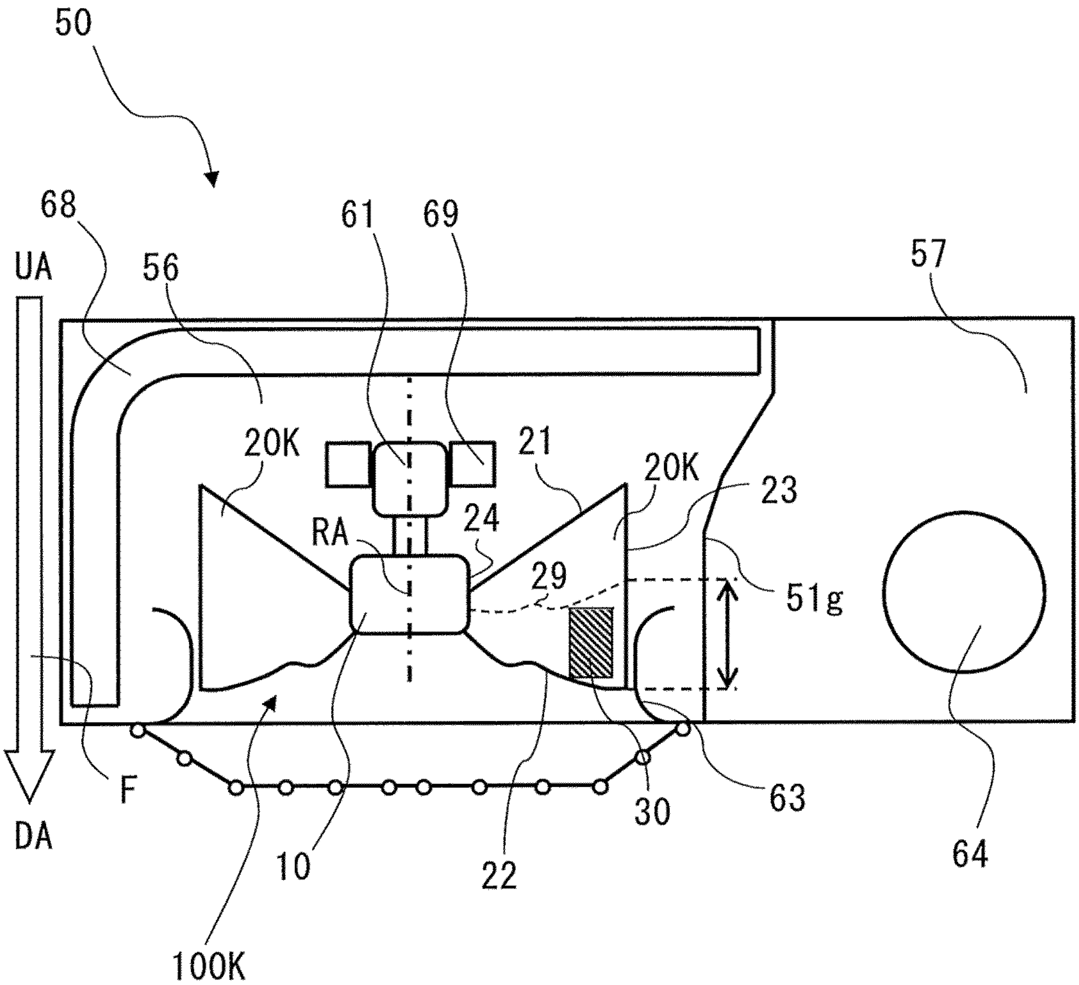

50
68
UA
56
61
69
57
20K
21
20K
23
RA
24
29
51g
F
DA
10
22
30
63
64
100K

FIG. 20

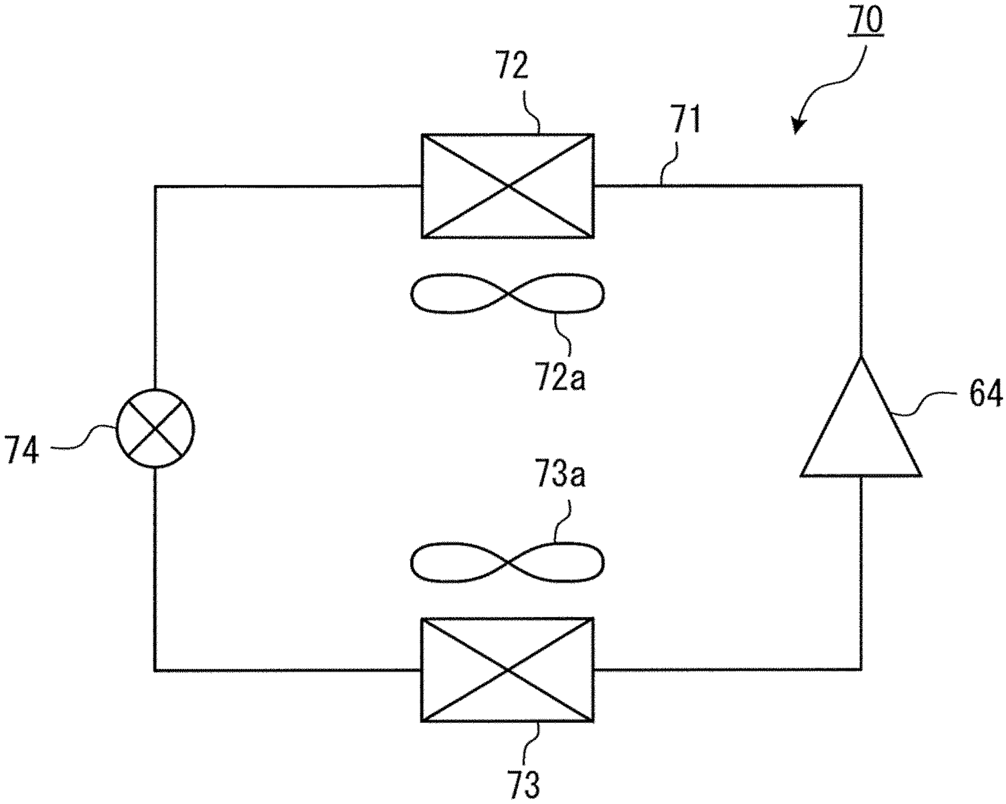


FIG. 21

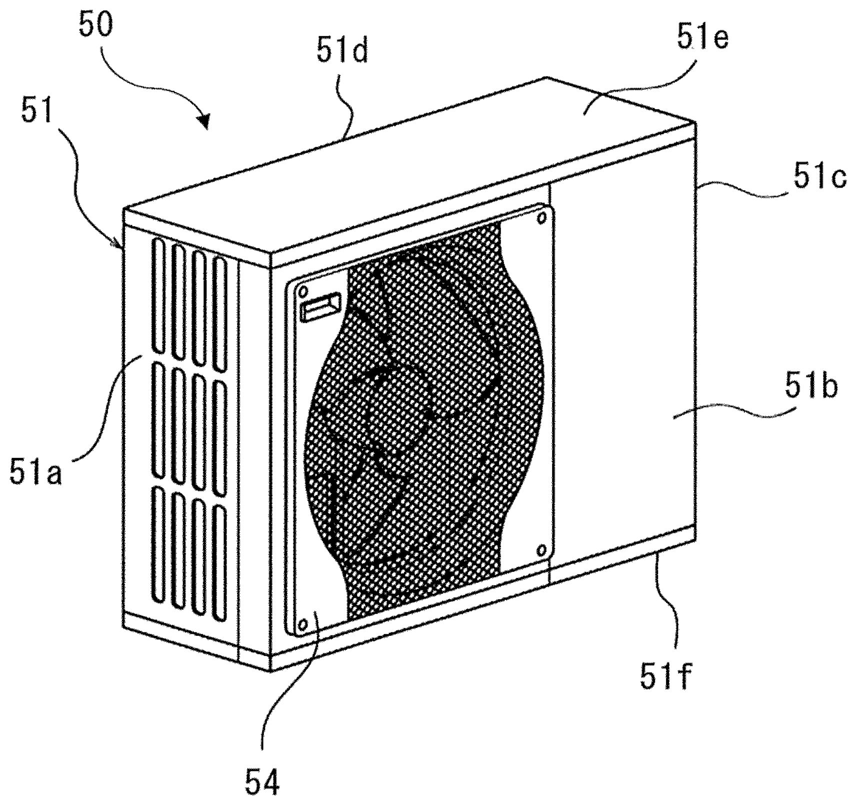
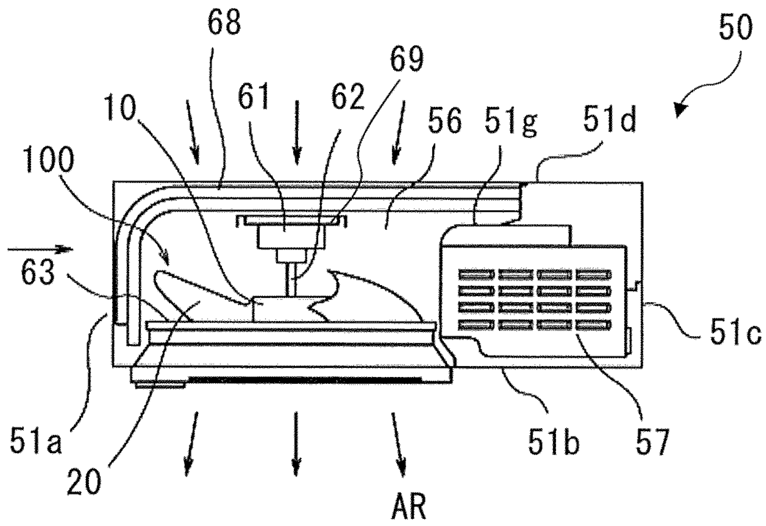

50
51d
51e
51
51c
51b
51a
51f
54

FIG. 22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69
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61
62
56
51g
51d
100
63
51c
51a
51b
57
20
AR

FIG. 23

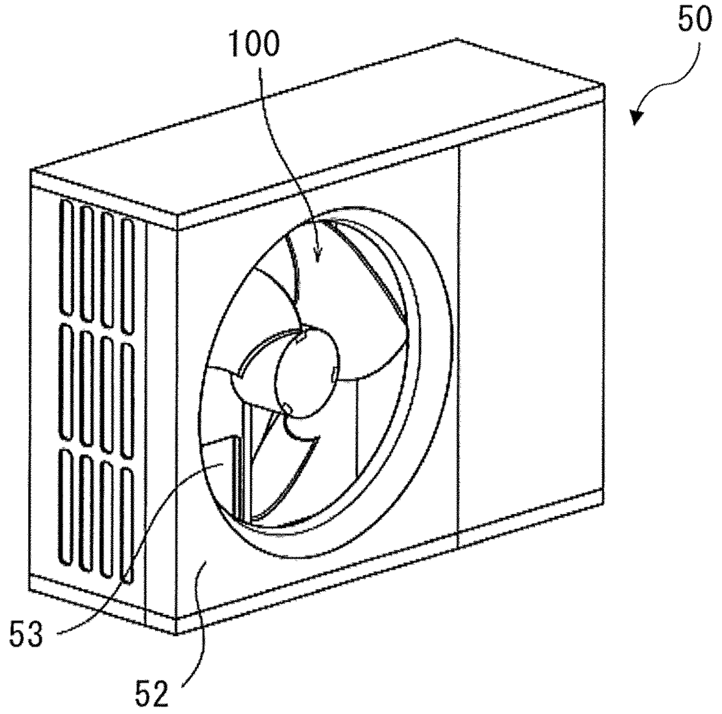
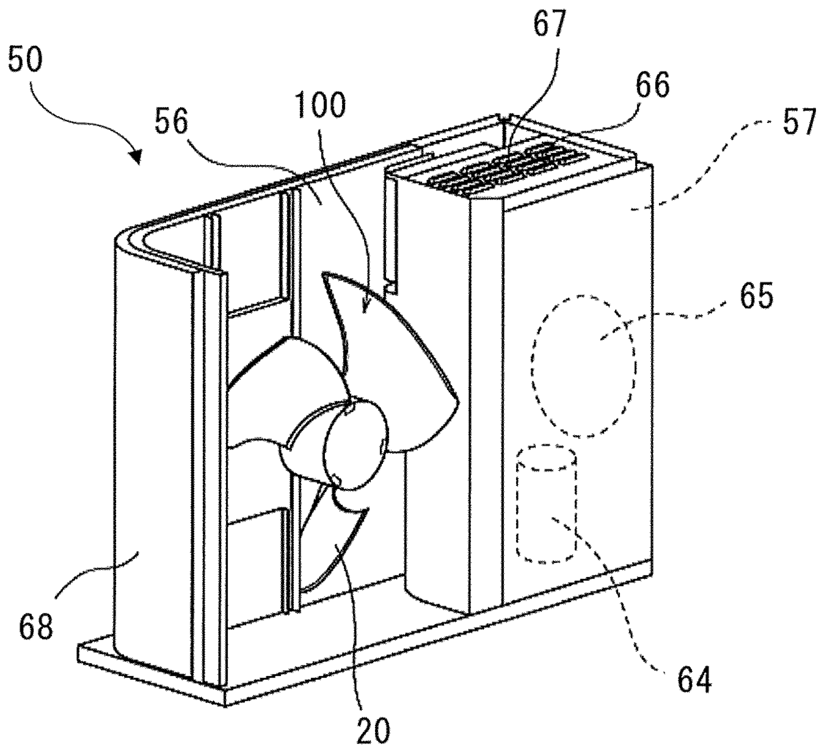


FIG. 24



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/044363

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F04D29/38(2006.01)i
FI: F04D29/38 A, F04D29/38 C

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. F04D29/38

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2011-179330 A (PANASONIC CORP.) 15 September 2011, paragraphs [0041]-[0056], fig. 1-8,	1, 3-5, 10-11, 13-14
A	paragraphs [0041]-[0056], fig. 1-8	2, 6-9, 12
X	WO 2016/071948 A1 (MITSUBISHI ELECTRIC CORP.) 12 May 2016, paragraphs [0010]-[0023], fig. 1-3,	1, 3-4, 10-11, 13-14
A	paragraphs [0010]-[0023], fig. 1-3	2

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22.01.2020	04.02.2020

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

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2019/044363

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
JP 2011-179330 A	15.09.2011	CN 102168686 A paragraphs [0070]-[0086], fig. 1-8	
WO 2016/071948 A1	12.05.2016	EP 3217018 A paragraphs [0012]-[0025], fig. 1-3	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2011236860 A **[0004]**