(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 098 885 A1

(12) # EUROPEAN PATENT APPLICATION

published in accordance with Art. 153(4) EPC

(43) Date of publication:
07.12.2022 Bulletin 2022/49

(21) Application number: **20916541.4**

(22) Date of filing: **30.01.2020**

(51) International Patent Classification (IPC):
F04D 29/30 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04D 29/30

(86) International application number:
PCT/JP2020/003435

(87) International publication number:
WO 2021/152775 (05.08.2021 Gazette 2021/31)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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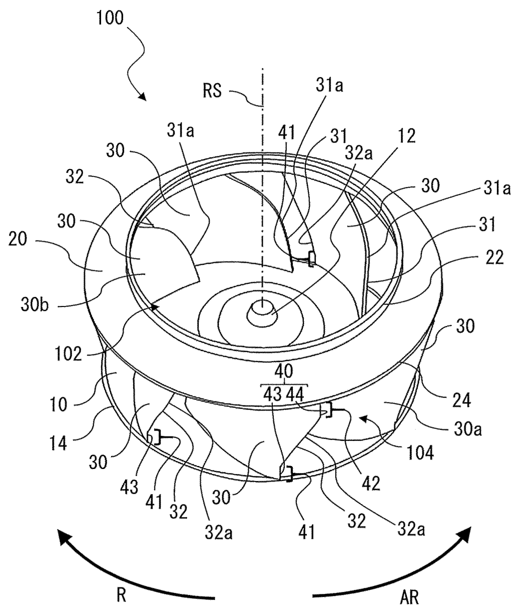
(54) **CENTRIFUGAL BLOWER AND AIR CONDITIONER PROVIDED WITH SAME**

(57) A centrifugal fan includes a backing plate to be driven to rotate, an annular rim facing the backing plate, and a plurality of blades disposed between the backing plate and the rim. Each of the plurality of blades has a trailing edge positioned on a positive side in an anti-rotational direction relative to a leading edge. The trailing edge includes a first trailing edge junction being a junction with the backing plate, and a second trailing edge junction being a junction with the rim. The second trailing edge junction is positioned on a positive side in the anti-rotational direction relative to the first trailing edge junction. The first trailing edge junction and the second trailing edge junction include a trailing-edge straight portion parallel to a rotational axis of the backing plate.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to a centrifugal fan that sucks air in a direction of a rotational axis and blows the air with its direction changed to a radial direction, and relates to an air-conditioning apparatus including the centrifugal fan.

Background Art

[0002] Hitherto, there is proposed a centrifugal fan that sucks gas in a direction of a rotational axis and blows the gas in a direction intersecting the rotational axis. The centrifugal fan includes a backing plate that rotates about the rotational axis, a plurality of blades annularly disposed about the rotational axis, and a rim disposed so that the plurality of blades are interposed between the rim and the backing plate in the direction of the rotational axis (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2005-155510

Summary of Invention

Technical Problem

[0004] In the centrifugal fan structured as in Patent Literature 1, airflows at junctions between each blade and the backing plate and between the blade and the rim are likely to become turbulent due to corners between the wall surface of the blade and the wall surface of the backing plate and between the wall surface of the blade and the wall surface of the rim. Particularly in a three-dimensional blade shape in which the trailing edge of each blade extends in an anti-rotational direction from the backing plate toward the rim, the blade is inclined relative to the backing plate and the rim. Therefore, the airflow is likely to become turbulent at a part having an acute angle between the blade and the backing plate or the rim.

[0005] The present disclosure has been made to solve the problem described above and provides a centrifugal fan reduced in terms of air turbulence at junctions between each blade and a backing plate and between the blade and a rim, and provides an air-conditioning apparatus including the centrifugal fan.

Solution to Problem

[0006] A centrifugal fan according to an embodiment of the present disclosure includes a backing plate to be driven to rotate, an annular rim facing the backing plate, and a plurality of blades disposed between the backing plate and the rim. Each of the plurality of blades has a trailing edge positioned on a positive side in an anti-rotational direction relative to a leading edge. The trailing edge includes a first trailing edge junction being a junction with the backing plate, and a second trailing edge junction being a junction with the rim. The second trailing edge junction is positioned on a positive side in the anti-rotational direction relative to the first trailing edge junction. The first trailing edge junction and the second trailing edge junction include a trailing-edge straight portion parallel to a rotational axis of the backing plate.

Advantageous Effects of Invention

[0007] In the centrifugal fan according to the embodiment of the present disclosure, the first trailing edge junction being a junction between the trailing edge and the backing plate and the second trailing edge junction being a junction between the trailing edge and the rim include the trailing-edge straight portion parallel to the rotational axis. Therefore, the speed difference between a pressure surface and a suction surface of the blade is reduced at the first trailing edge junction and the second trailing edge junction. Thus, air turbulence is reduced.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a perspective view of a centrifugal fan according to Embodiment 1.
[Fig. 2] Fig. 2 is a side view of the centrifugal fan according to Embodiment 1.
[Fig. 3] Fig. 3 is a perspective view of a centrifugal fan according to Embodiment 2.
[Fig. 4] Fig. 4 is a perspective view of a centrifugal fan according to Embodiment 3.
[Fig. 5] Fig. 5 is a vertical sectional view of a centrifugal fan according to Embodiment 4.
[Fig. 6] Fig. 6 is an internal structural diagram of an indoor unit of an air-conditioning apparatus including a centrifugal fan according to Embodiment 5.
[Fig. 7] Fig. 7 is a structural diagram of the air-conditioning apparatus according to Embodiment 5.

Description of Embodiments

[0009] A centrifugal fan 100 and an air-conditioning apparatus 200 according to each of Embodiments 1 to 5 are described below with reference to the drawings. In the drawings including Fig. 1 to which reference is made below, the relative relationship of dimensions of constituent elements and the shapes thereof may differ from an actual relationship and actual shapes. In the drawings to which reference is made below, elements represented by the same reference signs are identical or corresponding elements and are common throughout the description herein. Terms of directions (for example, "up", "down", "right", "left", "front", and "rear") are used as appropriate for facilitating understanding. Those terms are used only for convenience of the description but do not limit dispositions and directions of devices or components.

Embodiment 1.

[Structure of Centrifugal Fan 100]

[0010] Fig. 1 is a perspective view of a centrifugal fan 100 according to Embodiment 1. Fig. 2 is a side view of the centrifugal fan 100 according to Embodiment 1. In Fig. 1, a rotational direction R is a direction in which the centrifugal fan 100 and a backing plate 10 rotate, and an anti-rotational direction AR is a direction opposite to the direction in which the centrifugal fan 100 and the backing plate 10 rotate. The basic structure of the centrifugal fan 100 is described with reference to Fig. 1 and Fig. 2.

[0011] The centrifugal fan 100 is driven to rotate by a motor or other devices (not illustrated). The centrifugal fan 100 sucks gas in a direction of a rotational axis RS and forcibly sends air radially outward with a centrifugal force generated by the rotation. The centrifugal fan 100 includes the backing plate 10 serving as a rotator, an annular rim 20 facing the backing plate 10, and a plurality of blades 30 provided between the backing plate 10 and the rim 20.

(Backing Plate 10)

[0012] The backing plate 10 is a rotator that rotates about the rotational axis RS. The backing plate 10 has a circular shape when projected along the rotational axis RS of the centrifugal fan 100. A radially central part of the backing plate 10 has a substantially conical shape to project like a mountain toward the rim 20. That is, the backing plate 10 has an inclined surface extending away from an air inlet 102 described later with increasing distance from the center to the outer periphery.

[0013] The backing plate 10 has a boss 12 at a central part of the backing plate 10, that is, at the top of the mountain-like projection. The boss 12 is a part where a rotational shaft of the motor (not illustrated) is fixed. The rotational shaft of the motor is connected to the boss 12. The backing plate 10 is driven by the motor (not illustrated) to rotate about the rotational axis RS. The rotational axis RS is a rotational axis of the backing plate 10 and is also a rotational axis of the centrifugal fan 100.

[0014] The backing plate 10 may have any shape other than the shape described above as long as the backing plate 10 is the rotator having the boss 12. For example, the backing plate 10 may have a disc shape or a polygonal shape when projected along the rotational axis RS. The radially central part of the backing plate 10 may project like a mountain and a radially outer part of the backing plate 10, that is, a ring-shaped part around the projecting radially central part may have a substantial flat-plate shape.

(Rim 20)

[0015] The rim 20 faces the backing plate 10. The rim 20 is a so-called shroud. The rim 20 couples the plurality of blades 30 to keep a positional relationship among the distal ends of the blades 30 and increase the strength of the plurality of blades 30.

[0016] The rim 20 serves as an air introduction wall at an air inlet part of the centrifugal fan 100. The rim 20 has an annular shape in plan view in the direction of the rotational axis RS, and has an arc shape in cross section along the rotational axis RS.

[0017] More specifically, the rim 20 has a ring shape when projected along the rotational axis RS of the centrifugal fan 100. The rim 20 projects like a mountain from a radially outer part toward a radially central part. The rim 20 has the air inlet 102 at the center.

[0018] The air inlet 102 for gas is defined by an inner peripheral edge 22 that is an edge on the inner periphery of the rim 20. The diameter of the rim 20 increases with decreasing distance from the air inlet 102 to the backing plate 10. In the cross section along the rotational axis RS, the rim 20 has a curved shape to expand toward the backing plate 10.

[0019] A rim outer peripheral edge portion 24 constituting the outer peripheral edge of the ring-shaped rim 20 has the largest diameter among components of the rim 20, and is positioned closest to the backing plate 10. As illustrated in Fig. 2, an outside diameter OS of the rim 20 is larger than an outside diameter OM of the backing plate 10. The structure of the centrifugal fan 100 is not limited to the structure in which the outside diameter OS of the rim 20 is larger than the outside diameter OM of the backing plate 10. In the centrifugal fan 100, the outside diameter OS of the rim 20 may be equal to the outside diameter OM of the backing plate 10 or may be smaller than the outside diameter OM of the backing plate 10.

[0020] The backing plate 10 and the rim 20 are disposed away from each other in the direction of the rotational axis RS. In the centrifugal fan 100, the rim outer peripheral edge portion 24 of the rim 20 and a backing-plate outer peripheral edge portion 14 of the backing plate 10 define an air outlet 104 between the rim outer peripheral edge portion 24 and the backing-plate outer peripheral edge portion 14.

[0021] The rim outer peripheral edge portion 24 is an outer peripheral edge portion of the rim 20 in the radial direction, and constitutes the outer peripheral edge of the rim 20 as described above. The backing-plate outer peripheral edge portion 14 is an outer peripheral edge portion of the backing plate 10 in the radial direction, and constitutes the outer peripheral edge of the backing plate 10. The air outlet 104 is an opening where air sucked into the centrifugal fan 100 through the air inlet 102 is discharged by rotation of the centrifugal fan 100.

(Blades 30)

[0022] Each blade 30 rotates together with the backing plate 10 during rotation of the backing plate 10 to generate an airflow from the center toward the outer periphery of the backing plate 10. The plurality of blades 30 are disposed between the backing plate 10 and the rim 20. In each of the plurality of blades 30, one end in the direction of the rotational axis RS of the centrifugal fan 100 is joined to the backing plate 10, and the other end in the direction of the rotational axis RS is joined to the rim 20.

[0023] The plurality of blades 30 are disposed on a circle about the rotational axis RS. The blades 30 are disposed at predetermined intervals in a circumferential direction of the backing plate 10. Each blade 30 extends rearward in the rotational direction R of the backing plate 10.

[0024] In each of the plurality of blades 30, an inner peripheral end 31 is positioned closer to the rotational axis RS than is an outer peripheral end 32. In each of the plurality of blades 30, the inner peripheral end 31 is positioned at a predetermined distance from the rotational axis RS, and the outer peripheral end 32 is positioned near the backing-plate outer peripheral edge portion 14 and the rim outer peripheral edge portion 24. An imaginary line extended from a straight chord line connecting the inner peripheral end 31 and the outer peripheral end 32 of each blade 30 does not pass through the rotational axis RS. That is, the inner peripheral end 31 is positioned forward in the rotational direction R relative to a radial imaginary line connecting the rotational axis RS and the outer peripheral end 32.

[0025] The inner peripheral end 31 constitutes a leading edge 31a of the blade 30. The outer peripheral end 32 constitutes a trailing edge 32a of the blade 30. The leading edge 31a of the blade 30 is positioned on a positive side in the rotational direction R relative to the trailing edge 32a. The leading edge 31a of the blade 30 extends in the anti-rotational direction AR from the backing plate 10 toward the rim 20. The trailing edge 32a of the blade 30 is positioned on a positive side in the anti-rotational direction AR relative to the leading edge 31a. The trailing edge 32a of the blade 30 extends in the anti-rotational direction AR from the backing plate 10 toward the rim 20.

[0026] The trailing edge 32a of the blade 30 includes a first trailing edge junction 41 with the backing plate 10, and a second trailing edge junction 42 with the rim 20. The first trailing edge junction 41 is a root of the trailing edge 32a near the backing plate 10. The second trailing edge junction 42 is a root of the trailing edge 32a near the rim 20. The first trailing edge junction 41 and the second trailing edge junction 42 are offset in the rotational direction R. The second trailing edge junction 42 is positioned on a positive side in the anti-rotational direction AR relative to the first trailing edge junction 41.

[0027] The first trailing edge junction 41 and the second trailing edge junction 42 include a trailing-edge straight portion 40 parallel to the rotational axis RS of the backing plate 10. The trailing-edge straight portion 40 includes a first trailing-edge straight portion 43 at the first trailing edge junction 41, and a second trailing-edge straight portion 44 at the second trailing edge junction 42.

[0028] The first trailing edge junction 41 has the first trailing-edge straight portion 43 parallel to the rotational axis RS of the backing plate 10. The first trailing edge junction 41 may be constituted by the first trailing-edge straight portion 43 alone or may have the first trailing-edge straight portion 43 as a part in the direction of the rotational axis RS. For example, the first trailing edge junction 41 may have a curved portion having an arc shape between the first trailing-edge straight portion 43 and the backing plate 10 to connect the blade 30 and the backing plate 10 by a smooth curved surface. In the case where the first trailing edge junction 41 has the curved portion, stress concentration at the first trailing edge junction 41 of the blade 30 is mitigated.

[0029] The second trailing edge junction 42 has the second trailing-edge straight portion 44 parallel to the rotational axis RS of the backing plate 10. The second trailing edge junction 42 may be constituted by the second trailing-edge straight portion 44 alone or may have the second trailing-edge straight portion 44 as a part in the direction of the rotational axis RS. For example, the second trailing edge junction 42 may have a curved portion having an arc shape between the second trailing-edge straight portion 44 and the rim 20 to connect the blade 30 and the rim 20 by a smooth curved surface. In the case where the second trailing edge junction 42 has the curved portion, stress concentration at the second trailing edge junction 42 of the blade 30 is mitigated.

[0030] It is desirable that the trailing edge 32a of the blade 30 have both the first trailing-edge straight portion 43 of the first trailing edge junction 41 and the second trailing-edge straight portion 44 of the second trailing edge junction 42. The trailing edge 32a of the blade 30 may have either the first trailing-edge straight portion 43 of the first trailing edge junction 41 or the second trailing-edge straight portion 44 of the second trailing edge junction 42. That is, in the trailing edge 32a of the blade 30, at least one of the junction of the blade 30 near the rim 20 and the junction of the blade 30 near the backing plate 10 may have the trailing-edge straight portion 40 parallel to the rotational axis RS of the backing plate 10.

[0031] The blade 30 has an outer blade surface 30a as one surface and an inner blade surface 30b as the other surface in the radial direction about the rotational axis RS. In the blade 30, the outer blade surface 30a is a pressure surface, and the inner blade surface 30b is a suction surface. The outer blade surface 30a distant from the rotational axis RS is positioned farther away from the rotational axis RS at a part closer to the rear in the rotational direction R. The inner blade surface 30b near the rotational axis RS is similarly positioned farther away from the rotational axis RS at a part closer to the rear in the rotational direction R while keeping a predetermined distance from the outer blade surface 30a. The thickness of the blade 30 that corresponds to the predetermined distance gradually decreases from the center toward the inner peripheral end 31 and the outer peripheral end 32. That is, the sectional shape of the blade 30 in a plane perpendicular to the rotational axis RS is analogous to the shape of a general blade.

[0032] As illustrated in Fig. 2, an outside blade diameter OW of the centrifugal fan 100 is larger in a range AS between the rim 20 and an intermediate point HB of the opening width of the air outlet 104 than at the intermediate point HB. The outside blade diameter OW of the centrifugal fan 100 is smaller in a range AM between the backing plate 10 and the intermediate point HB of the opening width of the air outlet 104 than at the intermediate point HB.

[0033] The centrifugal fan 100 has the maximum value of the outside blade diameter OW at a point closer to the rim 20 than the intermediate point HB of the opening width of the air outlet 104, and the minimum value of the outside blade diameter OW at a point closer to the backing plate 10 than the intermediate point HB. The opening width of the air outlet 104 is a distance between the backing-plate outer peripheral edge portion 14 of the backing plate 10 and the rim outer peripheral edge portion 24 of the rim 20 in the direction of the rotational axis RS. The outside blade diameter OW is a diameter of the centrifugal fan 100 at a portion of the blade 30. In other words, the outside blade diameter OW is a diameter of a rotational circle drawn by the outer peripheral end 32 of the blade 30 by the rotation of the centrifugal fan 100 while the centrifugal fan 100 is operating.

[0034] The centrifugal fan 100 need not essentially have the maximum value of the outside blade diameter OW at the point closer to the rim 20 than the intermediate point HB of the opening width of the air outlet 104, and the minimum value of the outside blade diameter OW at the point closer to the backing plate 10 than the intermediate point HB. For example, the centrifugal fan 100 may have a structure in which the outside blade diameter OW at the point closer to the rim 20 than the intermediate point HB is equal to the outside blade diameter OW at the point closer to the backing plate 10 than the intermediate point HB.

[Operation of Centrifugal Fan 100]

[0035] When the backing plate 10 of the centrifugal fan 100 is rotated by the rotation of the motor connected to the boss 12, the blades 30 fixed to the backing plate 10 move in the circumferential direction about the rotational axis RS. When the backing plate 10 rotates in the rotational direction R, air outside the centrifugal fan 100 is sucked, through the air inlet 102, into a space defined by the backing plate 10, the rim 20, and the plurality of blades 30. When the blades 30 of the centrifugal fan 100 rotate together with the backing plate 10, the air sucked into the space defined by the backing plate 10 and the plurality of blades 30 is caused to pass between the adjacent blades 30 and sent outward in the radial direction of the backing plate 10.

[Advantageous Effects of Centrifugal Fan 100]

[0036] In general, the airflow is likely to become turbulent at the corner of each blade near the junction with the rim or the backing plate. The first trailing edge junction 41 and the second trailing edge junction 42 of the centrifugal fan 100 have the first trailing-edge straight portion 43 and the second trailing-edge straight portion 44 parallel to the rotational axis RS of the backing plate 10, respectively. With the first trailing-edge straight portion 43 and the second trailing-edge straight portion 44 of the centrifugal fan 100, the blade 30 and each of the backing plate 10 and the rim 20 are connected at a right angle along the trailing edge 32a on both the pressure surface and the suction surface of the blade 30. Therefore, in the centrifugal fan 100, the speed difference between the pressure surface and the suction surface of the blade 30 is reduced at the trailing edge 32a of the blade 30. Thus, the air turbulence is reduced compared with a case where the trailing edge 32a of the blade 30 is connected to each of the backing plate 10 and the rim 20 at an acute angle. As a result, the centrifugal fan 100 can attain higher efficiency of the fan.

[0037] In general, the airflow is likely to become turbulent at the corner of each blade near the junction with the rim or the backing plate, and the efficiency of the centrifugal fan may decrease due to separation of the airflow from the blade. With the first trailing-edge straight portion 43 and the second trailing-edge straight portion 44 of the centrifugal fan 100, the air turbulence is reduced compared with the case where the trailing edge 32a of the blade 30 is connected to each of the backing plate 10 and the rim 20 at an acute angle. As a result, the separation of the airflow from the blade can be suppressed, and the centrifugal fan 100 can attain higher efficiency of the fan.

[0038] In general, the airflow is likely to become turbulent at the corner of each blade near the junction with the rim or the backing plate, and noise may be generated due to the air turbulence. With the first trailing-edge straight portion 43 and the second trailing-edge straight portion 44 of the centrifugal fan 100, the air turbulence is reduced compared with the case where the trailing edge 32a of the blade 30 is connected to each of the backing plate 10 and the rim 20 at an acute angle. As a result, the noise generated due to the air turbulence can be reduced in the centrifugal fan 100.

Embodiment 2.

[Structure of Centrifugal Fan 100A]

[0039] Fig. 3 is a perspective view of a centrifugal fan 100A according to Embodiment 2. Portions having the same structures as those of the centrifugal fan 100 in

Fig. 1 and Fig. 2 are represented by the same reference signs and description thereof is omitted. In the centrifugal fan 100A according to Embodiment 2, the structure of the leading edge 31a of the blade 30 in the centrifugal fan 100 according to Embodiment 1 is further specified. Thus, the following description is mainly made about the structure of the leading edge 31a of the blade 30 with reference to Fig. 3.

(Blades 30)

[0040] The leading edge 31a of the blade 30 includes a first leading edge junction 51 with the backing plate 10, and a second leading edge junction 52 with the rim 20. The first leading edge junction 51 is a root of the leading edge 31a near the backing plate 10. The second leading edge junction 52 is a root of the leading edge 31a near the rim 20. The first leading edge junction 51 and the second leading edge junction 52 are offset in the rotational direction R. The second leading edge junction 52 is positioned on a positive side in the anti-rotational direction AR relative to the first leading edge junction 51.

[0041] The first leading edge junction 51 has a first leading-edge straight portion 53 parallel to the rotational axis RS of the backing plate 10. The first leading edge junction 51 may be constituted by the first leading-edge straight portion 53 alone or may have the first leading-edge straight portion 53 as a part in the direction of the rotational axis RS. For example, the first leading edge junction 51 may have a curved portion having an arc shape between the first leading-edge straight portion 53 and the backing plate 10 to connect the blade 30 and the backing plate 10 by a smooth curved surface. In the case where the first leading edge junction 51 has the curved portion, stress concentration at the first leading edge junction 51 of the blade 30 is mitigated.

[0042] The second leading edge junction 52 has a second leading-edge straight portion 54 parallel to the rotational axis RS of the backing plate 10. The second leading edge junction 52 may be constituted by the second leading-edge straight portion 54 alone or may have the second leading-edge straight portion 54 as a part in the direction of the rotational axis RS. For example, the second leading edge junction 52 may have a curved portion having an arc shape between the second leading-edge straight portion 54 and the rim 20 to connect the blade 30 and the rim 20 by a smooth curved surface. In the case where the second leading edge junction 52 has the curved portion, stress concentration at the second leading edge junction 52 of the blade 30 is mitigated.

[0043] It is desirable that the leading edge 31a of the blade 30 have both the first leading-edge straight portion 53 of the first leading edge junction 51 and the second leading-edge straight portion 54 of the second leading edge junction 52. The leading edge 31a of the blade 30 may have either the first leading-edge straight portion 53 of the first leading edge junction 51 or the second leading-edge straight portion 54 of the second leading edge junction 52. That is, in the leading edge 31a of the blade 30, at least one of the junction of the blade 30 near the rim 20 and the junction of the blade 30 near the backing plate 10 may have the leading-edge straight portion parallel to the rotational axis RS of the backing plate 10.

[Advantageous Effects of Centrifugal Fan 100A]

[0044] In general, when an airflow moves onto each blade, the airflow is likely to become turbulent at the corner of the blade near the junction with the rim or the backing plate. The first leading edge junction 51 and the second leading edge junction 52 of the centrifugal fan 100A have the first leading-edge straight portion 53 and the second leading-edge straight portion 54 parallel to the rotational axis RS of the backing plate 10, respectively. With the first leading-edge straight portion 53 and the second leading-edge straight portion 54 of the centrifugal fan 100A, the blade 30 and each of the backing plate 10 and the rim 20 are connected at a right angle along the leading edge 31a on both the pressure surface and the suction surface of the blade 30. Therefore, in the centrifugal fan 100A, the difference between the angles of the pressure surface and the suction surface of the blade 30 from the backing plate 10 and the rim 20 is reduced at the leading edge 31a. Thus, the air turbulence is reduced compared with a case where the leading edge 31a of the blade 30 is connected to each of the backing plate 10 and the rim 20 at an acute angle. As a result, the centrifugal fan 100A can attain higher efficiency of the fan.

[0045] In general, when an airflow moves onto each blade, the airflow is likely to become turbulent at the corner of the blade near the junction with the rim or the backing plate, and noise may be generated due to the air turbulence. With the first leading-edge straight portion 53 and the second leading-edge straight portion 54 of the centrifugal fan 100A, the air turbulence is reduced compared with the case where the leading edge 31a of the blade 30 is connected to each of the backing plate 10 and the rim 20 at an acute angle. As a result, the noise generated due to the air turbulence can be reduced in the centrifugal fan 100A.

Embodiment 3.

[Structure of Centrifugal Fan 100B]

[0046] Fig. 4 is a perspective view of a centrifugal fan 100B according to Embodiment 3. Portions having the same structures as those of the centrifugal fan 100 and the other centrifugal fan in Fig. 1 to Fig. 3 are represented by the same reference signs and description thereof is omitted. In the centrifugal fan 100B according to Embodiment 3, the structure of the trailing edge 32a of the blade 30 in the centrifugal fan 100 according to Embodiment 1 is further specified. Thus, the following description is mainly made about the structure of the trailing edge 32a of the blade 30 with reference to Fig. 4.

[0047] As described above, the trailing-edge straight portion 40 includes the first trailing-edge straight portion 43 at the first trailing edge junction 41, and the second trailing-edge straight portion 44 at the second trailing edge junction 42. In a direction parallel to the direction of the rotational axis RS, the length of the first trailing-edge straight portion 43 is a length L1, and the length of the second trailing-edge straight portion 44 is a length L2.

[0048] In the centrifugal fan 100B, the length L2 of the second trailing-edge straight portion 44 is larger than the length L1 of the first trailing-edge straight portion 43 (length L2 > length L1).

[Advantageous Effects of Centrifugal Fan 100B]

[0049] In general, in the centrifugal fan, the air speed of the airflow is lower near the rim than near the backing plate, and the airflow is likely to become turbulent. With the first trailing-edge straight portion 43 and the second trailing-edge straight portion 44 of the centrifugal fan 100B, the blade 30 and each of the backing plate 10 and the rim 20 are connected at a right angle along the trailing edge 32a on both the pressure surface and the suction surface of the blade 30. Therefore, in the centrifugal fan 100B, the speed difference between the pressure surface and the suction surface of the blade 30 is reduced at the trailing edge 32a of the blade 30. Thus, the air turbulence is reduced compared with the case where the trailing edge 32a of the blade 30 is connected to each of the backing plate 10 and the rim 20 at an acute angle. In the centrifugal fan 100B, the length L2 of the second trailing-edge straight portion 44 is larger than the length L1 of the first trailing-edge straight portion 43. Thus, the air turbulence can further be reduced near the rim 20 where the air turbulence is likely to occur.

Embodiment 4.

[Structure of Centrifugal Fan 100C]

[0050] Fig. 5 is a vertical sectional view of a centrifugal fan 100C according to Embodiment 4. Portions having the same structures as those of the centrifugal fan 100 and the other centrifugal fans in Fig. 1 to Fig. 4 are represented by the same reference signs and description thereof is omitted. In the centrifugal fan 100C according to Embodiment 4, the structure of the air outlet 104 in the centrifugal fan 100 according to Embodiment 1 is further specified. Thus, the following description is mainly made about the structure of the air outlet 104 with reference to Fig. 5.

[0051] As described above, the rim 20 of the centrifugal fan 100C defines the air inlet 102 for gas by the inner peripheral edge 22. The backing plate 10 and the rim 20 of the centrifugal fan 100C define the air outlet 104 for gas between the backing-plate outer peripheral edge portion 14 constituting the outer peripheral edge of the backing plate 10 and the rim outer peripheral edge portion 24 constituting the outer peripheral edge of the rim 20.

[0052] As shown by an arrow D2 in Fig. 5, the rim outer peripheral edge portion 24 is oriented in the radial direction in a cross section parallel to the rotational axis RS. That is, in the cross section parallel to the rotational axis RS, the direction in which a part of the rim outer peripheral edge portion 24 extends corresponds to the radial direction. Assuming that a rim extension 20a is an imaginary part of the rim 20 extended from the rim outer peripheral edge portion 24 in the cross section parallel to the rotational axis RS, the direction in which the rim extension 20a extends corresponds to the radial direction.

[0053] The backing plate 10 has a slope 10a inclined away from the air inlet 102 with increasing distance from the inner periphery to the outer periphery in the cross section parallel to the rotational axis RS. In the backing plate 10, the region between the boss 12 and the backing-plate outer peripheral edge portion 14 may be constituted by the slope 10a alone or the slope 10a may be provided as a part of the region between the boss 12 and the backing-plate outer peripheral edge portion 14. It is desirable that the backing-plate outer peripheral edge portion 14 define the outer peripheral edge of the slope 10a in the cross section parallel to the rotational axis RS.

[0054] As shown by an arrow D1 in Fig. 5, the backing-plate outer peripheral edge portion 14 defines the outer peripheral edge of the slope 10a and is oriented in a direction opposite to the direction to the part where the air inlet 102 is provided. Assuming that a backing plate extension 10b is an imaginary part of the backing plate 10 extended from the backing-plate outer peripheral edge portion 14 in the cross section parallel to the rotational axis RS, the direction in which the backing plate extension 10b extends from the backing-plate outer peripheral edge portion 14 corresponds to the direction opposite to the direction to the part where the air inlet 102 is provided. In the cross section parallel to the rotational axis RS, the backing plate extension 10b is inclined relative to the direction parallel to the rotational axis RS and relative to the radial direction.

[0055] When the centrifugal fan 100C rotates, gas is sucked into the centrifugal fan 100C through the air inlet 102 defined by the inner peripheral edge 22 of the rim 20, and is discharged out of the centrifugal fan 100C through the air outlet 104 defined between the backing-plate outer peripheral edge portion 14 and the rim outer peripheral edge portion 24. In the direction in which the gas flows inside the centrifugal fan 100C, the backing-plate outer peripheral edge portion 14 is a downstream end of the backing plate 10, and the rim outer peripheral edge portion 24 is a downstream end of the rim 20. In the cross section parallel to the rotational axis RS, the downstream end of the rim 20 is oriented in the radial direction. In the cross section parallel to the rotational axis RS, the downstream end of the backing plate 10 is inclined relative to the downstream end of the rim 20 in a direction opposite to the direction to the suction side of the fan.

[Advantageous Effects of Centrifugal Fan 100C]

[0056] In the centrifugal fan 100C, the trailing edge 32a of the blade 30 has the second trailing-edge straight portion 44 near the rim 20. Therefore, the air turbulence is reduced. Thus, in the centrifugal fan 100C, the airflow to be blown from the centrifugal fan 100C moves easily along the rim 20 and the backing plate 10 even if the airflow expands radially outward.

[0057] In the cross section parallel to the rotational axis of the centrifugal fan 100C, the rim outer peripheral edge portion 24 that is the airflow downstream end of the rim 20 is oriented in the radial direction. In the centrifugal fan 100C, the backing-plate outer peripheral edge portion 14 that is the airflow downstream end of the backing plate 10 defines the outer peripheral edge of the slope 10a and is oriented in the direction opposite to the direction to the part where the air inlet 102 is provided. In the centrifugal fan 100C, the airflow near the rim 20 is blown horizontally and the airflow near the backing plate 10 is blown away from the suction side along the inclination of the slope 10a of the backing plate 10. Therefore, the airflow to be blown from the centrifugal fan 100C expands radially outward. For the airflow to be blown from the centrifugal fan 100C, the air speed decreases and the static pressure is recovered by a diffuser effect.

[0058] As described above, the air speed of the airflow to be blown radially outward from the centrifugal fan 100C decreases by the diffuser effect obtained by the orientation of the rim outer peripheral edge portion 24 of the rim 20 and the orientation of the backing-plate outer peripheral edge portion 14 of the backing plate 10. Therefore, in an air-conditioning apparatus in which the centrifugal fan 100C is surrounded by wall surfaces, a loss caused by impingement of the airflow blown from the centrifugal fan 100C on the wall surfaces of the air-conditioning apparatus is suppressed.

Embodiment 5.

[Structure of Indoor Unit 150 of Air-Conditioning Apparatus 200]

[0059] Fig. 6 is an internal structural diagram of an indoor unit 150 of an air-conditioning apparatus 200 including a centrifugal fan 100 according to Embodiment 5. Fig. 7 is a structural diagram of the air-conditioning apparatus 200 according to Embodiment 5. The indoor unit 150 of the air-conditioning apparatus 200 is a floor-standing apparatus. The indoor unit 150 of the air-conditioning apparatus 200 is not limited to the floor-standing apparatus but may be any other type of apparatus such as a ceiling-concealed apparatus.

[0060] The indoor unit 150 of the air-conditioning apparatus 200 includes a casing 210 that is an outer shell of the indoor unit 150, a heat exchanger 220 disposed in the casing 210, and the centrifugal fan 100 that is disposed in the casing 210 and forms an airflow passing through the heat exchanger 220.

(Casing 210)

[0061] The casing 210 has a cubic shape. The shape of the casing 210 is not limited to the cubic shape but may be any other shape such as a columnar shape, a prism shape, a conical shape, a shape including a plurality of corners, or a shape including a plurality of curves.

[0062] A top portion 211 of the casing 210 has an air inlet 212. A bottom portion 213 of the casing 210 has an air outlet 214. The air inlet 212 is an opening where air is sucked into the casing 210 from the outside by the operation of the centrifugal fan 100. The air outlet 214 is an opening where air is discharged out of the casing 210 from the inside by the operation of the centrifugal fan 100. The positions of the air inlet 212 and the air outlet 214 are not limited to those in this structure. For example, the air inlet 212 and the air outlet 214 may be provided on the same plane, that is, either the top portion 211 or the bottom portion 213. Alternatively, one of the air inlet 212 and the air outlet 214 or both the air inlet 212 and the air outlet 214 may be provided on the side of the casing 210.

[0063] The casing 210 houses the centrifugal fan 100 and the heat exchanger 220. The internal space of the casing 210 is partitioned by a partition plate 215 into a space S11 including the heat exchanger 220 and a space S12 including the centrifugal fan 100. The casing 210 includes an electrical component 250 that controls the air-conditioning apparatus 200.

(Centrifugal Fan 100)

[0064] The centrifugal fan 100 is one or more centrifugal fans out of the centrifugal fans 100 to 100C according to Embodiments 1 to 4. The number of centrifugal fans 100 disposed in the casing 210 is not limited to one but may be plural. The centrifugal fan 100 forms an airflow that is sucked into the casing 210 through the air inlet 212 of the casing 210 and is blown toward an air-conditioned space through the air outlet 214 of the casing 210.

[0065] The centrifugal fan 100 includes a bellmouth 230. The bellmouth 230 is disposed between the partition plate 215 and the centrifugal fan 100. The centrifugal fan 100 is connected to a motor 240. The motor 240 is supported by a motor support 241 fixed to the bottom portion 213 of the casing 210. The motor 240 has an output shaft 242. The boss 12 of the centrifugal fan 100 is attached to the output shaft 242 of the motor 240.

(Heat Exchanger 220)

[0066] The heat exchanger 220 is disposed on an upstream side of the centrifugal fan 100 in a direction of the airflow formed in the casing 210 by the centrifugal fan 100. The heat exchanger 220 adjusts the temperature of air that is sucked into the casing 210 through the air inlet

212 of the casing 210 and is blown toward the air-conditioned space through the air outlet 214. The heat exchanger 220 may have a publicly known structure.

[0067] A removable filter 221 is disposed on an upstream side of the heat exchanger 220 in the direction of the airflow formed in the casing 210 by the centrifugal fan 100. The filter 221 removes dust in air before the air passes through the heat exchanger 220. A drain pan 222 is provided below the heat exchanger 220 to collect condensed water.

[Operation of Indoor Unit 150 of Air-Conditioning Apparatus 200]

[0068] When the centrifugal fan 100 rotates, air in the air-conditioned space is sucked into the casing 210 through the air inlet 212 of the casing 210. The air sucked into the casing 210 passes through the filter 221 and then through the heat exchanger 220. The air passing through the heat exchanger 220 exchanges heat with refrigerant flowing through the heat exchanger 220 and the temperature and humidity are adjusted while the air passes through the heat exchanger 220.

[0069] The air having passed through the heat exchanger 220 is guided by the bellmouth 230 and sucked into the centrifugal fan 100. The air sucked into the centrifugal fan 100 passes between the blades 30 and is blown outward in the radial direction of the backing plate 10. The air blown from the centrifugal fan 100 is discharged to the air-conditioned space through the air outlet 214 in the bottom portion 213 of the casing 210.

[Overall Structure of Air-Conditioning Apparatus 200]

[0070] The air-conditioning apparatus 200 transfers heat between outdoor air and indoor air via refrigerant to heat or cool a room, thereby performing air conditioning. The air-conditioning apparatus 200 includes an outdoor unit 140 and the indoor unit 150. In the air-conditioning apparatus 200, a refrigerant circuit through which the refrigerant circulates is formed by connecting the outdoor unit 140 and the indoor unit 150 by a refrigerant pipe 115 and a refrigerant pipe 117. The refrigerant pipe 115 is a gas pipe through which refrigerant in a gas phase flows. The refrigerant pipe 117 is a liquid pipe through which refrigerant in a liquid phase flows. Two-phase gas-liquid refrigerant may flow through the refrigerant pipe 117. In the refrigerant circuit of the air-conditioning apparatus 200, a compressor 101, a flow switching device 103, an outdoor heat exchanger 105, an expansion valve 107, and the heat exchanger 220 are sequentially connected via refrigerant pipes.

(Outdoor Unit 140)

[0071] The outdoor unit 140 includes the compressor 101, the flow switching device 103, the outdoor heat exchanger 105, and the expansion valve 107. The compressor 101 compresses sucked refrigerant and discharges the compressed refrigerant. Examples of the flow switching device 103 include a four-way valve. The flow switching device 103 changes the direction of a refrigerant passage. The air-conditioning apparatus 200 can achieve a heating operation or a cooling operation by changing a flow of refrigerant with the flow switching device 103 based on an instruction from a controller (not illustrated).

[0072] The outdoor heat exchanger 105 exchanges heat between refrigerant and outdoor air. During the heating operation, the outdoor heat exchanger 105 functions as an evaporator and exchanges heat between outdoor air and low-pressure refrigerant flowing into the outdoor heat exchanger 105 through the refrigerant pipe 117 to evaporate and gasify the refrigerant. During the cooling operation, the outdoor heat exchanger 105 functions as a condenser and exchanges heat between outdoor air and refrigerant compressed by the compressor 101 and flowing into the outdoor heat exchanger 105 from the flow switching device 103 to condense and liquify the refrigerant.

[0073] The outdoor heat exchanger 105 is provided with an outdoor fan 111 to increase the efficiency of the heat exchange between the refrigerant and the outdoor air. The outdoor fan 111 may be provided with an inverter that changes an operation frequency of a fan motor to change the rotation speed of a fan.

[0074] The expansion valve 107 is an expansion device (flow rate control device). The flow rate control device functions as the expansion valve by controlling the flow rate of refrigerant flowing through the expansion valve 107. The expansion valve 107 regulates the pressure of refrigerant by changing its opening degree. For example, if the expansion valve 107 is an electronic expansion valve, the opening degree is adjusted based on an instruction from the controller (not illustrated).

(Indoor Unit 150)

[0075] The indoor unit 150 includes the heat exchanger 220 that exchanges heat between refrigerant and indoor air, and the centrifugal fan 100 that regulates a flow of air to be subjected to the heat exchange by the heat exchanger 220.

[0076] During the heating operation, the heat exchanger 220 functions as a condenser and exchanges heat between indoor air and refrigerant flowing into the heat exchanger 220 through the refrigerant pipe 115 to condense and liquify the refrigerant. Then, the refrigerant flows out of the heat exchanger 220 toward the refrigerant pipe 117. During the cooling operation, the heat exchanger 220 functions as an evaporator and exchanges heat between indoor air and refrigerant having a low pressure through the expansion valve 107 so that the refrigerant removes heat from the air. Thus, the refrigerant is evaporated and gasified and then flows out of the heat exchanger 220 toward the refrigerant pipe 115. The centrifugal fan 100 faces the heat exchanger 220.

[Examples of Operation of Air-Conditioning Apparatus 200]

[0077] Next, the cooling operation is described as an example of the operation of the air-conditioning apparatus 200. High-temperature and high-pressure gas refrigerant compressed and discharged by the compressor 101 flows into the outdoor heat exchanger 105 via the flow switching device 103. The gas refrigerant flowing into the outdoor heat exchanger 105 is condensed into low-temperature refrigerant by exchanging heat with outdoor air sent by the outdoor fan 111. The low-temperature refrigerant flows out of the outdoor heat exchanger 105. The refrigerant flowing out of the outdoor heat exchanger 105 is expanded by the expansion valve 107 and the pressure is reduced to turn into low-temperature and low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the heat exchanger 220 of the indoor unit 150 and is evaporated into low-temperature and low-pressure gas refrigerant by exchanging heat with indoor air sent by the centrifugal fan 100. The low-temperature and low-pressure gas refrigerant flows out of the heat exchanger 220. At this time, the indoor air cooled by the refrigerant that removes heat from the indoor air becomes conditioned air and is blown to the air-conditioned space through the air outlet 214 of the indoor unit 150. The gas refrigerant flowing out of the heat exchanger 220 is sucked into the compressor 101 via the flow switching device 103 and is compressed again. The operation described above is repeated.

[0078] Next, the heating operation is described as an example of the operation of the air-conditioning apparatus 200. High-temperature and high-pressure gas refrigerant compressed and discharged by the compressor 101 flows into the heat exchanger 220 of the indoor unit 150 via the flow switching device 103. The gas refrigerant flowing into the heat exchanger 220 is condensed into low-temperature refrigerant by exchanging heat with indoor air sent by the centrifugal fan 100. The low-temperature refrigerant flows out of the heat exchanger 220. At this time, the indoor air heated by receiving heat from the gas refrigerant becomes conditioned air and is blown to the air-conditioned space through the air outlet 214 of the indoor unit 150. The refrigerant flowing out of the heat exchanger 220 is expanded by the expansion valve 107 and the pressure is reduced to turn into low-temperature and low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the outdoor heat exchanger 105 of the outdoor unit 140 and is evaporated into low-temperature and low-pressure gas refrigerant by exchanging heat with outdoor air sent by the outdoor fan 111. The low-temperature and low-pressure gas refrigerant flows out of the outdoor heat exchanger 105. The gas refrigerant flowing out of the outdoor heat exchanger 105 is sucked into the compressor 101 via the flow switching device 103 and is compressed again. The operation described above is repeated.

[Advantageous Effects of Air-Conditioning Apparatus 200]

[0079] Since the air-conditioning apparatus 200 according to Embodiment 5 includes, for example, the centrifugal fan 100 according to Embodiment 1, the air-conditioning apparatus 200 can attain advantageous effects similar to those of, for example, the centrifugal fan 100 according to Embodiment 1. In the air-conditioning apparatus 200, the air turbulence in the centrifugal fan 100 can be reduced compared with an air-conditioning apparatus without the centrifugal fan 100. As a result, the air-conditioning apparatus 200 can attain higher efficiency of the fan. Further, noise due to the air turbulence can be reduced in the air-conditioning apparatus 200.

[0080] Embodiments 1 to 5 may be combined with each other. The structures described in Embodiments 1 to 5 are illustrative and may be combined with other publicly known technologies or partially omitted or modified without departing from the gist.

Reference Signs List

[0081] 10: backing plate, 10a: slope, 10b: backing plate extension, 12: boss, 14: backing-plate outer peripheral edge portion, 20: rim, 20a: rim extension, 22: inner peripheral edge, 24: rim outer peripheral edge portion, 30: blade, 30a: outer blade surface, 30b: inner blade surface, 31: inner peripheral end, 31a: leading edge, 32: outer peripheral end, 32a: trailing edge, 40: trailing-edge straight portion, 41: first trailing edge junction, 42: second trailing edge junction, 43: first trailing-edge straight portion, 44: second trailing-edge straight portion, 51: first leading edge junction, 52: second leading edge junction, 53: first leading-edge straight portion, 54: second leading-edge straight portion, 100: centrifugal fan, 100A: centrifugal fan, 100B: centrifugal fan, 100C: centrifugal fan, 101: compressor, 102: air inlet, 103: flow switching device, 104: air outlet, 105: outdoor heat exchanger, 107: expansion valve, 111: outdoor fan, 115: refrigerant pipe, 117: refrigerant pipe, 140: outdoor unit, 150: indoor unit, 200: air-conditioning apparatus, 210: casing, 211: top portion, 212: air inlet, 213: bottom portion, 214: air outlet, 215: partition plate, 220: heat exchanger, 221: filter, 222: drain pan, 230: bellmouth, 240: motor, 241: motor support, 242: output shaft, 250: electrical component

Claims

1. A centrifugal fan, comprising:

a backing plate to be driven to rotate;
an annular rim facing the backing plate; and
a plurality of blades disposed between the backing plate and the rim,

each of the plurality of blades having a leading edge and a trailing edge, the trailing edge being positioned on a positive side in an anti-rotational direction relative to a leading edge,
the trailing edge comprising:

a first trailing edge junction being a junction with the backing plate; and
a second trailing edge junction being a junction with the rim,

the second trailing edge junction being positioned on a positive side in the anti-rotational direction relative to the first trailing edge junction,
the first trailing edge junction and the second trailing edge junction comprising a trailing-edge straight portion parallel to a rotational axis of the backing plate.

2. The centrifugal fan of claim 1,

wherein the leading edge comprises:

a first leading edge junction being a junction with the backing plate; and
a second leading edge junction being a junction with the rim,

wherein the second leading edge junction is positioned on a positive side in the anti-rotational direction relative to the first leading edge junction, and
wherein the first leading edge junction and the second leading edge junction comprise a leading-edge straight portion parallel to the rotational axis of the backing plate.

3. The centrifugal fan of claim 1 or 2,

wherein the trailing-edge straight portion comprises:

a first trailing-edge straight portion at the first trailing edge junction; and
a second trailing-edge straight portion at the second trailing edge junction, and

wherein a length of the second trailing-edge straight portion is larger than a length of the first trailing-edge straight portion.

4. The centrifugal fan of any one of claims 1 to 3,

wherein an air inlet for gas is defined by an inner peripheral edge of the rim,
wherein an air outlet for gas is defined between a backing-plate outer peripheral edge portion constituting an outer peripheral edge of the backing plate and a rim outer peripheral edge portion constituting an outer peripheral edge of the rim, and
wherein, in a cross section parallel to the rotational axis, the rim outer peripheral edge portion is oriented in a radial direction, the backing plate has a slope inclined away from the air inlet with increasing distance from an inner periphery to an outer periphery, and the backing-plate outer peripheral edge portion defines an outer peripheral edge of the slope and is oriented in a direction opposite to a direction to a part where the air inlet is provided.

5. An air-conditioning apparatus, comprising:

the centrifugal fan of any one of claims 1 to 4; and
a heat exchanger.

FIG. 1

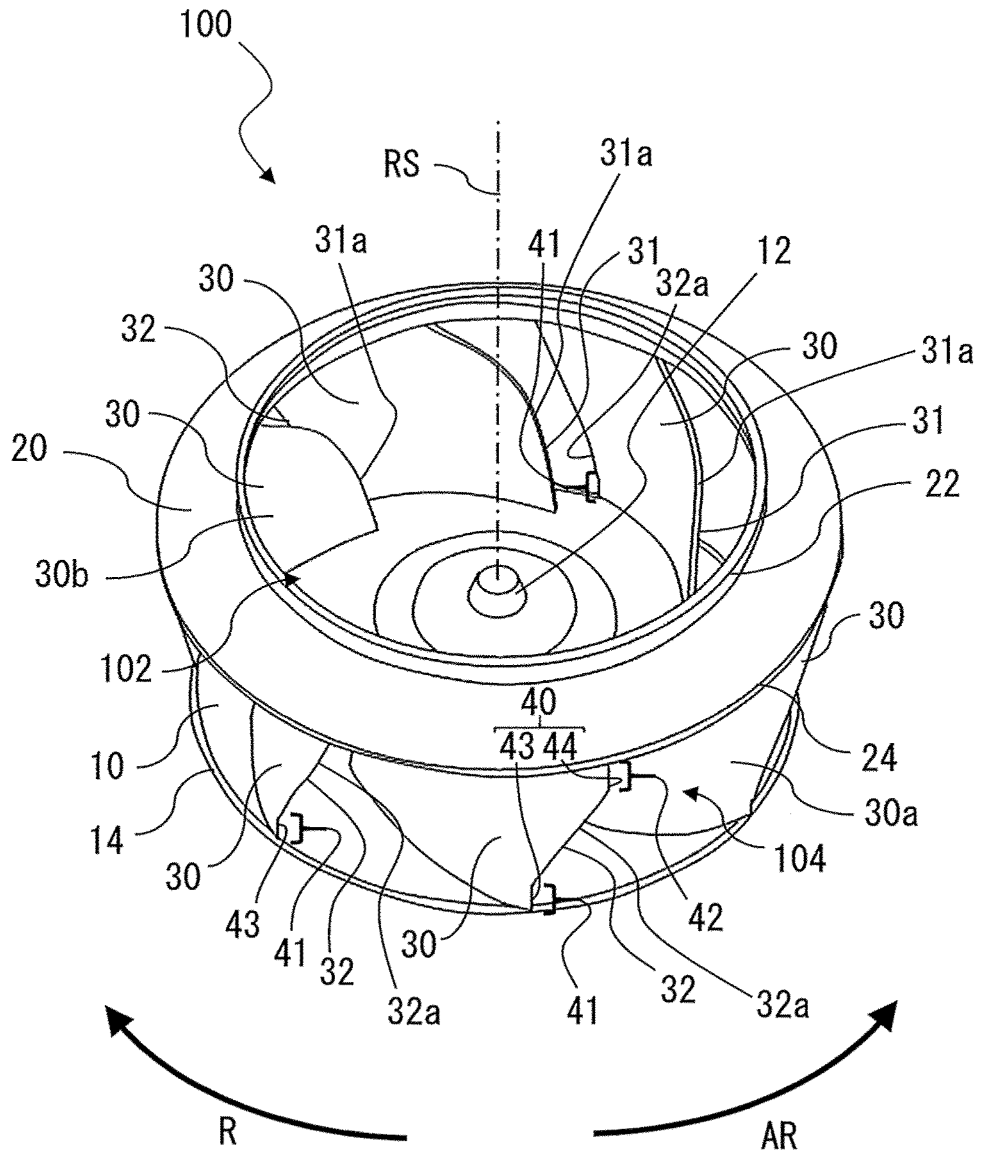
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FIG. 2

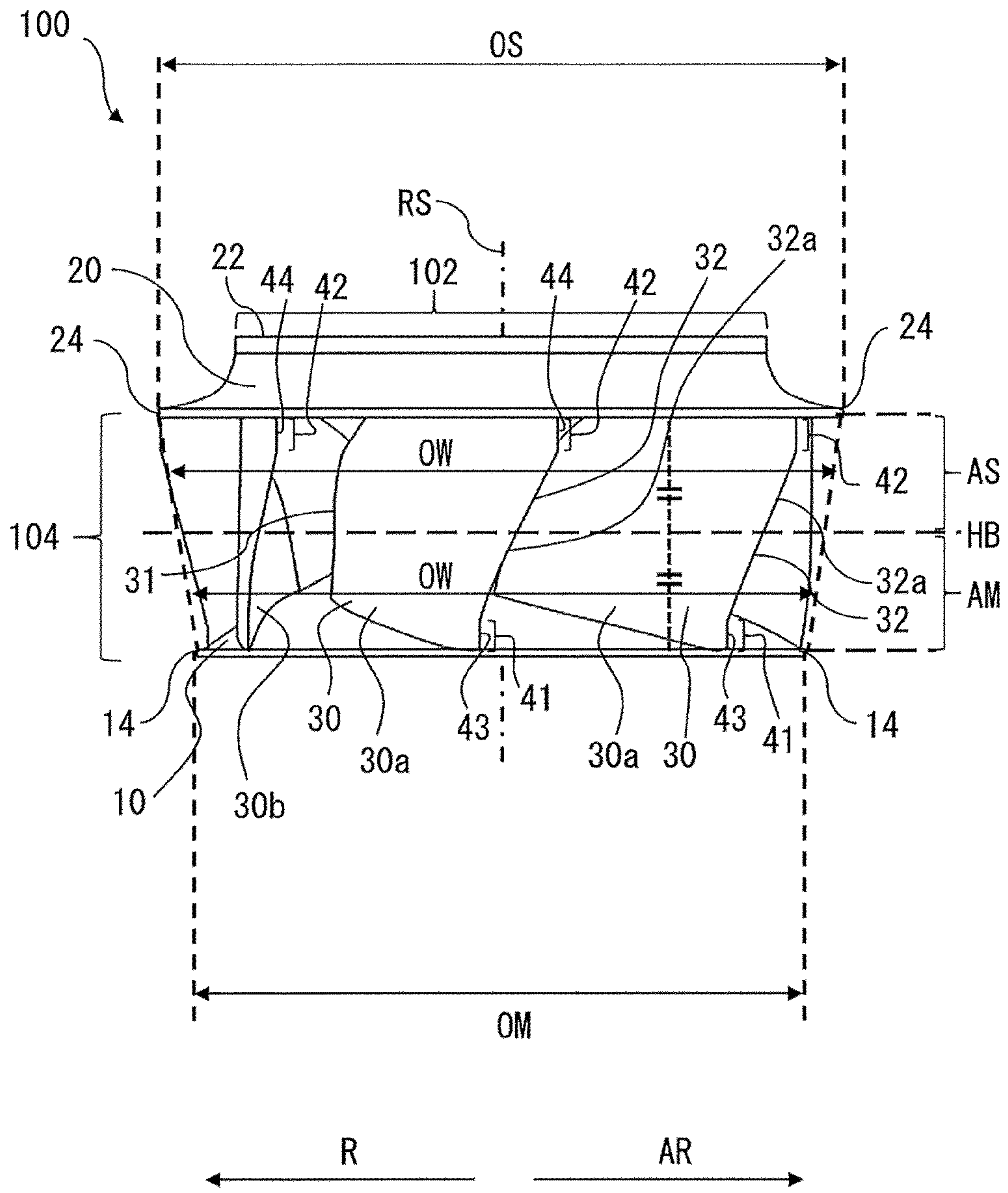
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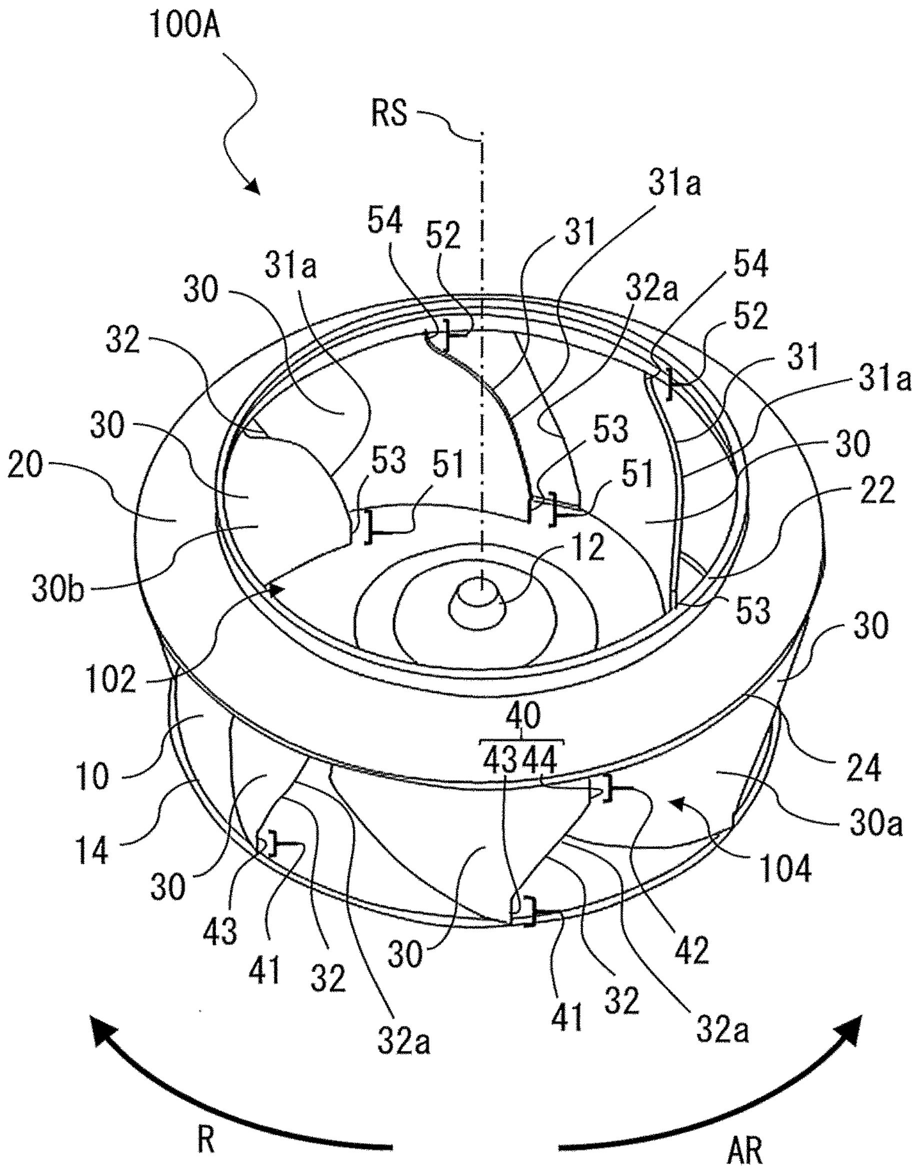
FIG. 3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30b
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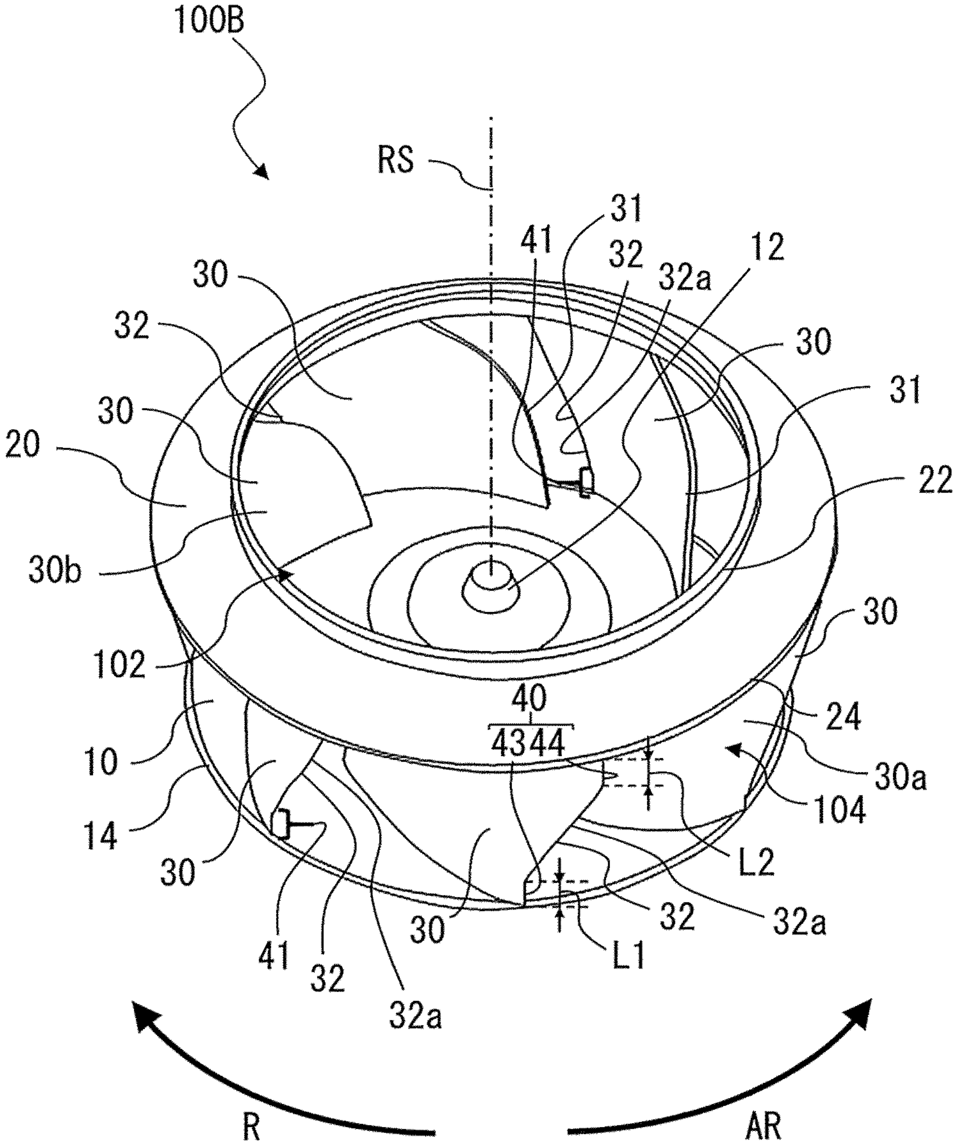
FIG. 4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L2
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L1
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FIG. 5

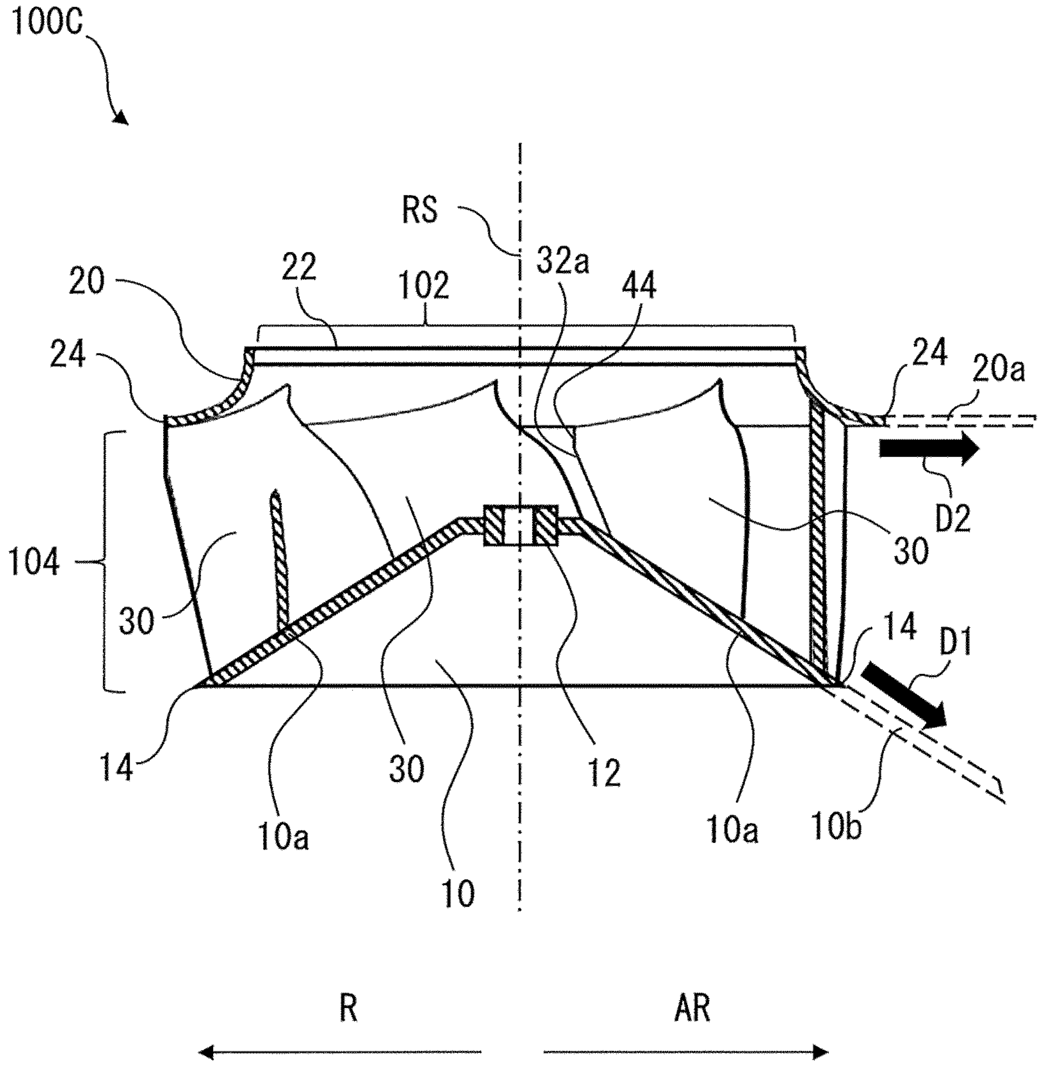
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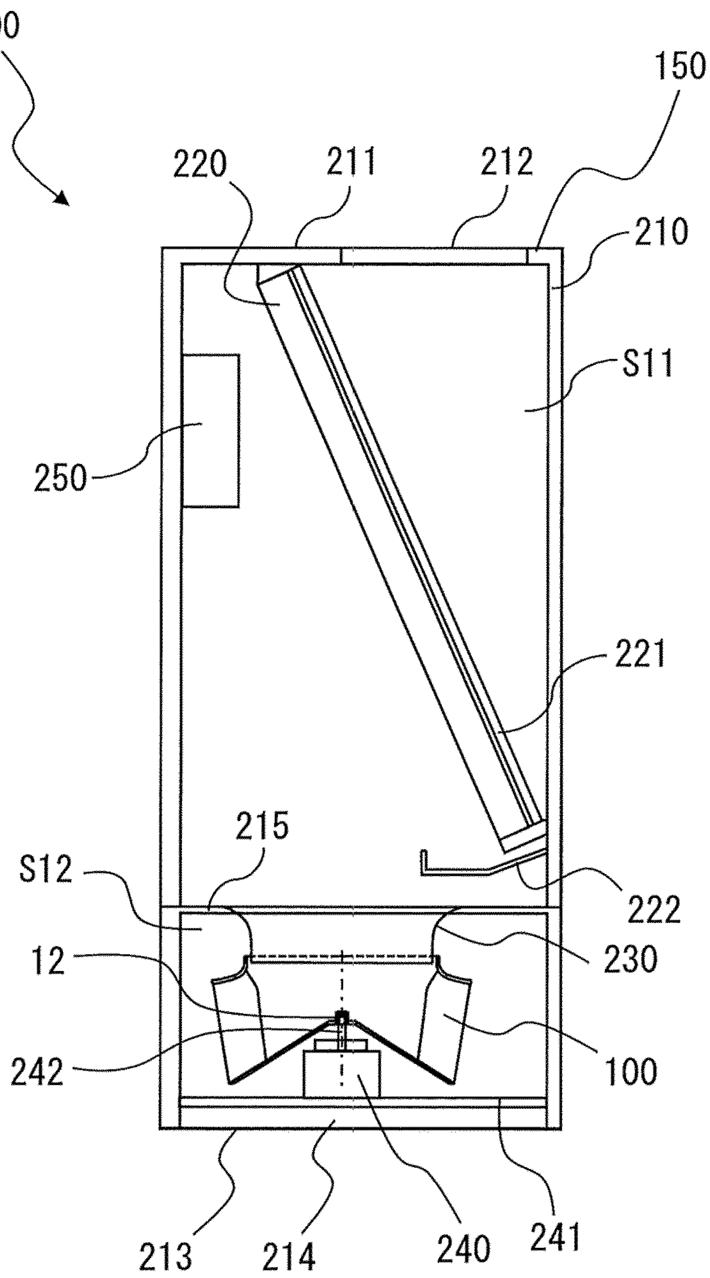
FIG. 6


200
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S11
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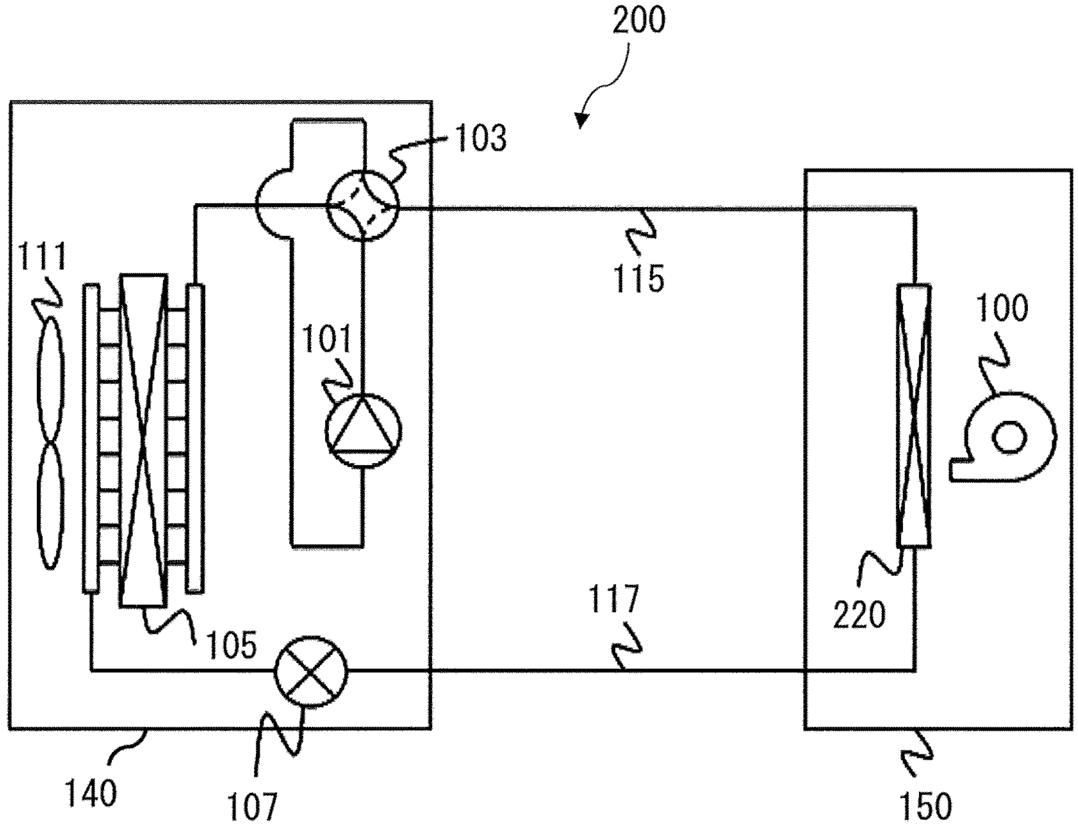
FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/003435

A. CLASSIFICATION OF SUBJECT MATTER
F04D 29/30(2006.01)i
FI: F04D29/30 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)
F04D29/30

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
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 2008-223760 A (DAIKIN INDUSTRIES, LTD.) 25.09.2008 (2008-09-25) paragraphs [0043]-[0061], fig. 1-5	1, 3, 5
Y	paragraphs [0043]-[0061], fig. 1-5	4
A	paragraphs [0043]-[0061], fig. 1-5	2
Y	CN 204344519 U (ZHEJIANG LANGDI CROUP LTD.) 20.05.2015 (2015-05-20) paragraph [0024], fig. 2-4	4

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 March 2020 (25.03.2020)	07 April 2020 (07.04.2020)

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/JP2020/003435

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2008-223760 A	25 Sep. 2008	WO 2008/099854 A1	
CN 204344519 U	20 May 2015	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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