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

(11) EP 2 549 114 A1

(12) # EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
23.01.2013 Bulletin 2013/04

(21) Application number: **10847797.7**

(22) Date of filing: **18.03.2010**

(51) Int Cl.:
F04D 17/04 ^(2006.01) ***F04D 29/26*** ^(2006.01)

(86) International application number:
PCT/JP2010/001945

(87) International publication number:
WO 2011/114375 (22.09.2011 Gazette 2011/38)

(84) Designated Contracting States:
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 SE SI SK SM TR

(71) Applicant: **Mitsubishi Electric Corporation**
Tokyo 100-8310 (JP)

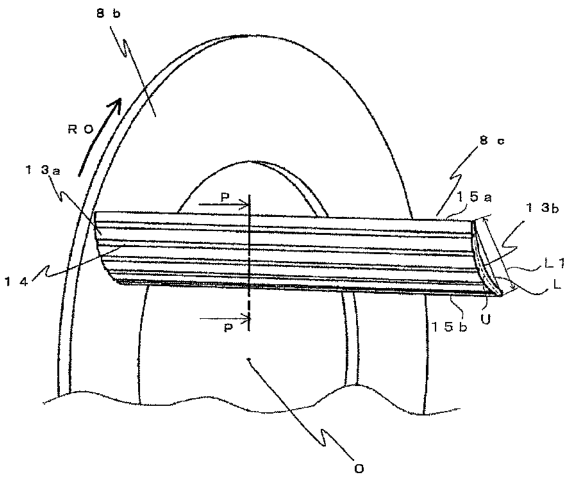
(72) Inventors:
- **IKEDA, Takashi**
  Tokyo 100-8310 (JP)
- **TADOKORO, Takahide**
  Tokyo 100-8310 (JP)
- **YAMASHITA, Tetsuo**
  Tokyo 100-8310 (JP)
- **HIRAKAWA, Seiji**
  Tokyo 100-8310 (JP)
- **SHIROTA, Mitsuhiro**
  Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner GbR**
Theresienhöhe 13
80339 München (DE)

(54) **CROSS-FLOW FAN AND AIR CONDITIONER**

(57) Provided are impeller units 8d having disk-shaped support plates 8b, whose center of rotation is located in the center thereof, and a plurality of blades 8c extending in a rotation-axis direction and arranged along the outer peripheries of the support plates 8b, the support plates 8b supporting opposite ends of the blades; an impeller 8a formed of the multiple impeller units 8d that are fixed to each other in the rotation-axis direction; and a plurality of grooves 14 having a depressed shape that extend in the rotation-axis direction and are provided in a blade suction surface 13a serving as a back side in a rotational direction of each blade 8c. The grooves 14 are separated from each other by a predetermined distance such that a flat section M is provided between neighboring grooves 14.

F I G. 4



EP 2 549 114 A1

Description

Technical Field

[0001] The present invention relates to a cross flow fan used as air-sending means, and to an air-conditioning apparatus equipped with such a cross flow fan.

Background Art

[0002] As an example of a cross flow fan installed in an air-conditioning apparatus of the related art, there is one in which a suction surface of each blade is provided with grooves, small recesses, or small protrusions extending in the rotational direction in an area near the outer circumference side of an impeller (for example, see Patent Literature 1).

Citation List

Patent Literature

[0003]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 3-210093

Summary of Invention

Technical Problem

[0004] The cross flow fan discussed in Patent Literature 1 as an example of the cross flow fan of the related art is provided with grooves, small recesses, or small protrusions extending in the rotational direction on the suction surface of each blade in an area near the outer circumference side of the impeller. In the cross flow fan, a flow path is formed between an air inlet and an air outlet. When each of the blades constituting the cross flow fan rotates so as to be positioned on the discharge side, the flow traveling along the blade becomes separated as the flow approaches the trailing edge thereof. This flow separation causes the pressure to fluctuate, thus causing noise. In Patent Literature 1, the grooves, small recesses, or small protrusions formed in the suction surface of each blade absorb the pressure fluctuations, which cause noise, so as to suppress wide-band noise, thereby achieving noise reduction. However, when the blade rotates so as to be positioned on the suction side, the direction in which the flow travels along the blade is reversed relative to that when the blade is positioned on the discharge side. Accordingly, the grooves, small recesses, or small protrusions will be located at the leading edge relative to the flow. This may cause the speed of flow to vary significantly in the longitudinal direction of the blade due to concentration of the flow in the small grooves, or the flow to become unstable due to the occurrence of flow separation at the side surfaces of the small recesses or generation of flow in the longitudinal direction of the blade by the small protrusions, which, in turn, may cause pressure fluctuations, possibly resulting in increased wide-band noise.

[0005] In the case where the cross flow fan is installed in an air-conditioning apparatus, flow separation tends to occur easily when the attack angle of the flow against the blades changes due to an increase in airflow resistance caused by dust adhered to a filter disposed at the suction side of the impeller. This is problematic in that the discharge flow becomes even more unstable. During cooling operation of the air-conditioning apparatus, when the discharge flow becomes unstable causing backflow to the fan from the room, cold air may flow into the impeller and condense into dew, dampening the floor if the dew condensation water were to be splattered to the outside.

[0006] Generally, when manufacturing the blades, thermoplastic resin, such as AS resin, is poured into a mold for the blades. After cooling the resin, the mold is released in the rotation-axis direction of the impeller such that blade sections are formed. However, in order to manufacture the blades each provided with grooves, small recesses, or small protrusions extending in the rotational direction (a direction perpendicular to the rotation axis) on the suction surface of the blade, as in Patent Literature 1, the mold needs to be released in the direction perpendicular to the rotation axis because the mold cannot be released in the rotation-axis direction. Disadvantageously, manufacturing process becomes complex and productivity becomes poor.

[0007] The present invention has been made to solve the aforementioned problems, and an object thereof is to obtain a low-noise, highly efficient cross flow fan. Another object is to obtain a quiet, energy-saving air-conditioning apparatus. Solution to Problem

[0008] A cross flow fan according to the invention includes impeller units including disk-shaped support plates whose center of rotation is located in a center thereof and a plurality of blades extending in a rotation-axis direction and arranged along outer peripheries of the support plates, the blades each being supported by the support plates at opposite ends; an impeller formed by fixing the impeller units in the rotation-axis direction; and a plurality of grooves having a depressed shape that extend in the rotation-axis direction, the grooves being provided on a blade suction surface serving as a back side in a rotational direction of each blade, in which the grooves are separated from each other by a predetermined distance such that a flat section is provided between neighboring grooves.

[0009] Furthermore, a cross flow fan according to the invention includes impeller units including disk-shaped support plates whose center of rotation is located in a center thereof and a plurality of blades extending in a rotation-axis direction and arranged along outer peripheries of the support plates, the blades each being supported by the support plates at opposite ends; an impeller formed by fixing the impeller units in the rotation-axis direction; a motor having a motor shaft that is fixed to the support plate located at an end of the impeller, the motor rotationally driving the impeller; a fixation section for the motor shaft that is located in one of a relevant impeller unit; and an opening formed by partially widening a pitch of the blades of the impeller units so that a fixing member is insertable into the fixation section, in which a plurality of grooves having a depressed shape and extending in the rotation-axis direction are provided on a blade suction surface serving as a back side in a rotational direction of at least a blade located adjacent to the opening on the rotational-direction side of the impeller.

[0010] Furthermore, a cross flow fan according to the invention includes impeller units including disk-shaped support plates whose center of rotation is located in a center thereof and a plurality of blades extending in a rotation-axis direction and arranged along outer peripheries of the support plates, the blades each being supported by the support plates at opposite ends; and an impeller formed by fixing the impeller units in the rotation-axis direction, in which a cross-sectional shape, taken in a direction perpendicular to the rotation axis, of one end of each blade that is a connection section connected to an associated support plate is larger than a cross-sectional shape, taken in the direction perpendicular to the rotation axis, of the other end of each blade that is a connection section connected to an associated support plate, and a plurality of grooves having a depressed shape and extending in the rotation-axis direction are provided in a blade suction surface serving as a back side in a rotational direction of the blade.

Furthermore, an air-conditioning apparatus according to the invention is equipped with the aforementioned cross flow fan.

Advantageous Effects of Invention

[0011] According to the invention, flow separation on the suction surface of each blade is suppressed so that stable flow is obtained, whereby a low-noise, highly efficient cross flow fan is advantageously obtained.

Moreover, by installing this cross flow fan in an air-conditioning apparatus, a quiet, energy-saving air-conditioning apparatus is obtained.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is an external perspective view illustrating an air-conditioning apparatus equipped with a cross flow fan according to Embodiment 1 of the invention.

[Fig. 2] Fig. 2 is a vertical cross-sectional view taken along line Q-Q of Fig. 1 and is a view corresponding to Embodiment 1 of the invention.

[Fig. 3] Fig. 3 is a schematic diagram illustrating an impeller of the cross flow fan according to Embodiment 1 of the invention.

[Fig. 4] Fig. 4 is a perspective view illustrating a state in which, for example, a blade is fixed to a ring and is a view corresponding to Embodiment 1 of the invention.

[Fig. 5] Fig. 5 is an enlarged cross-sectional view taken along line P-P of Fig. 4 and is a view corresponding to Embodiment 1 of the invention.

[Fig. 6] Fig. 6 is a cross section taken in a direction perpendicular to a rotation axis of the impeller and is an explanatory diagram illustrating the shape of grooves provided on a blade suction surface. The diagram corresponds to Embodiment 1 of the present invention.

[Fig. 7] Fig. 7 is a cross section taken in a direction perpendicular to a rotation axis of the impeller and is an explanatory diagram illustrating the shape of grooves provided on a blade suction surface. The diagram corresponds to Embodiment 1 of the present invention.

[Fig. 8] Fig. 8 is an explanatory diagram illustrating the flow of air when a blade 8c passes through a suction area E1 of the impeller and is a diagram corresponding to Embodiment 1 of the invention.

[Fig. 9] Fig. 9 is an explanatory diagram illustrating the flow of air when the blade passes through a discharge area E2 of the impeller and is a diagram corresponding to Embodiment 1 of the invention.

[Fig. 10] Fig. 10 is a perspective view illustrating an impeller of a cross flow fan according to Embodiment 2 of the invention.

[Fig. 11] Fig. 11 includes Fig. 11 (a) showing a partial perspective view of the impeller on the motor side and Fig. 11 (b) showing a side view thereof. The views correspond to Embodiment 2 of the invention.

[Fig. 12] Fig. 12 is a schematic diagram illustrating an impeller of a cross flow fan according to Embodiment 3 of the invention and includes Fig. 12(a) showing a side view of the cross flow fan and Fig. 12(b) showing a cross-sectional view taken along line S-S of Fig. 12(a).

[Fig. 13] Fig. 13 is a cross-sectional view of molds 17 and 18 and is a view corresponding to Embodiment 3 of the invention.

[Fig. 14] Fig. 14 is a cross-sectional view of one of blades taken along line A-A of Fig. 12 and is a view corresponding to Embodiment 3 of the invention.

[Fig. 15] Fig. 15 is a cross-sectional view of one of the blades taken along line B-B in Fig. 12 and is a view corresponding to Embodiment 3 of the invention.

[Fig. 16] Fig. 16 is a perspective view illustrating one of blades of another explanatory configuration of the cross flow fan according to Embodiment 3 of the invention.

[Fig. 17] Fig. 17 is a partially enlarged cross-sectional view of a tip of each blade in a longitudinal direction, taken in the direction perpendicular to the rotation axis and is a view corresponding to Embodiment 3 of the invention.

[Fig. 18] Fig. 18 illustrates another explanatory configuration of the cross flow fan according to Embodiment 3 of the invention and is a front view of one of the blades.

[Fig. 19] Fig. 19 illustrates further another explanatory configuration of the cross flow fan according to Embodiment 3 of the invention and is a front view of one of the blades.

[Fig. 20] Fig. 20 illustrates furthermore another explanatory configuration of the cross flow fan according to Embodiment 3 of the invention and is a front view of one of the blades.

[Fig. 21] Fig. 21 illustrates still another explanatory configuration of the cross flow fan according to Embodiment 3 of the invention and is a front view of one of the blades.

[Fig. 22] Fig. 22 illustrates still yet another explanatory configuration of the cross flow fan according to Embodiment 3 of the invention and is a front view of one of the blades.

Description of Embodiments

Embodiment 1

[0013] Embodiment 1 of the invention will be described below with reference to the drawings. Fig. 1 is an external perspective view illustrating an air-conditioning apparatus equipped with a cross flow fan according to Embodiment 1. Fig. 2 is a longitudinal sectional view taken along line Q-Q of Fig. 1. The flow of air is depicted by blank arrows in Fig. 1 and by dotted arrows in Fig. 2.

As shown in Figs. 1 and 2, an air-conditioning apparatus body 1 is set on a wall 11 a of a room 11 to be air-conditioned. An inlet grille 2 serving as an indoor air inlet, an electrostatic precipitator 6 that collects dust by applying static electricity thereto, and a meshed filter 5 for removing dust are provided at an upper portion 1 a of the air-conditioning apparatus body. Furthermore, a heat exchanger 7 formed of piping 7b penetrating through a plurality of aluminum fins 7a is disposed at the front side and the upper side of an impeller 8a so as to surround the impeller 8a. A front side 1 b of the air-conditioning apparatus body is covered with a front panel and an air outlet 3 is opened below. A cross flow fan 8 serving as an air-sending device separates a flow path into a suction side flow path E1 and a discharge side flow path E2 relative to the impeller 8a, and has a stabilizer 9 that temporarily stores water droplets dripping from the heat exchanger 7. Moreover, the cross flow fan 8 also has, on the discharge side of the impeller 8a, a helical guide wall 10 serving as a rear side of the discharge side flow path. Furthermore, vertical wind guide vanes 4a and horizontal wind guide vanes 4b are rotatably attached to the air outlet 3 so as to change the direction of air sent into the room. In the drawings, reference character O depicts the center of rotation of the impeller 8a, E1 depicts a suction area of the impeller 8a, and E2 depicts a discharge area of the impeller 8a. Moreover, reference character RO depicts a rotational direction of the impeller 8a.

[0014] In the air-conditioning apparatus body 1 having the above configuration, when a power supply board applies electricity to a motor that rotationally drives the impeller 8a, the impeller 8a of the cross flow fan 8 rotates in the RO direction. Thus, the air in the room 11 is taken in through the air inlet 2 provided at the upper portion 1 a of the air-conditioning apparatus body, and dust is removed from the air by the electrostatic precipitator 6 and the filter 5. Subsequently, the air undergoes heating operation, cooling operation, or dehumidifying operation by being heated, cooled, or dehumidified, respectively, by the heat exchanger 7 before the air is taken into the impeller 8a of the cross flow fan 8. Then, the air blown out from the impeller 8a is guided by the guide wall 10 towards the air outlet 3 and is blown out into the room 11, thus air-conditioning the room 11. In this case, the wind direction of the blown out air is controlled in the vertical and horizontal directions by the vertical wind guide vanes 4a and the horizontal wind guide vanes 4b, respectively, so that the wind is distributed throughout the entire room 11, thereby suppressing temperature variations within the room 11.

[0015] Fig. 3 is a schematic diagram illustrating the impeller 8a of the cross flow fan 8 according to Embodiment 1, and includes Fig. 3(a) showing a side view of the cross flow fan 8 and Fig. 3(b) showing a cross-sectional view taken along line N-N of Fig. 3(a). A lower half of Fig. 3 (b) shows a plurality of blades on the far side in a viewable state, whereas an upper half thereof shows one of blades 8c. As shown in Fig. 3, the impeller 8a of the cross flow fan 8 has a plurality of impeller units 8d in a rotation-axis direction AX. The impeller units 8d include disk-shaped support plates, for example, rings 8b in this case, whose center of rotation is located in the center thereof, and a plurality of blades 8c extending in the rotation-axis direction AX and arranged along the outer peripheries of the rings 8b. Both ends of each of the blades 8c are supported by the rings 8b. For example, multiple impeller units 8d formed with thermoplastic resin, such as AS resin or ABS resin, are prepared in the rotation-axis direction AX, and the ends of the blades 8c are joined to the rings 8b of neighboring impeller units 8d by, for example, ultrasonic welding. A fan shaft 8f is provided at the center of the ring 8b located at one end in the rotation-axis direction AX, and a fan boss 8e is provided at the center of the ring 8b located at the other end. The fan boss 8e and a motor shaft 12a of a motor 12 are fixed to each other by means of a screw or the like. The rings 8b are support plates with a circular outline. The rings 8b located at the opposite ends of the impeller 8a in the rotation-axis direction are respectively provided with the fan shaft 8f and the fan boss 8e in the central areas where the rotation axis is located. The rings 8b excluding those at the opposite ends have a ring shape and are hollow in the central areas where the rotation axis is located. In Fig. 3(b), a dot-dash line is an imaginary rotation-axis line that indicates the center O of rotation and connects the motor shaft 12a and the fan shaft 8f, and depicts the rotation-axis direction.

[0016] In Embodiment 1, multiple grooves 14 are formed on a blade suction surface 13a between a leading edge 15a and a trailing edge 15b of each blade 8c, as shown in Fig. 3. The blade profile will now be described in detail. A surface of each blade 8c that is on the rotational direction side and that receives pressure during rotation will be referred to as "blade pressure surface 13b", and a surface that is located opposite the blade pressure surface 13b and that becomes in a negative-pressure state during rotation will be referred to as "blade suction surface 13a". Fig. 4 is a perspective view illustrating a state where, for example, a single blade 8c is fixed to a single ring 8b, and Fig. 5 is an enlarged cross-sectional view taken along line P-P of Fig. 4. As shown in Fig. 4, the leading edge 15a of the blade 8c is located on the outer circumference side of the ring 8b, the trailing edge 15b of the blade 8c is located on the inner circumference side of the ring 8b, and a substantially circular arc shape is formed between the leading edge 15a and the trailing edge 15b. In a cross section taken in a direction perpendicular to the rotation axis of the blade 8c, a camber line U is a center line of a thickness of the blade 8c when not provided with the grooves 14, a chord line L is a straight line that connects the leading edge 15a and the trailing edge 15b of the blade 8c and L1 is the length of the chord line L.

[0017] Furthermore, as shown in Fig. 5, as compared with a blade thickness te1 at the leading edge 15a, which is circular-arc-shaped, and a blade thickness te2 (not shown) at the trailing edge 15b, a blade thickness te3 in a midsection, in the direction of the chord line L, of the blade 8c is configured to be thicker than the blade thickness te1 and the blade thickness te2. Specifically, a maximum blade thickness section 15c having a maximum thickness tmax in the direction of the chord line L is located between the leading edge 15a and the trailing edge 15b of the blade 8c, such that the thickness increases gradually from the leading edge 15a toward the maximum blade thickness section 15c and then decreases gradually from the maximum blade thickness section 15c toward the trailing edge 15b.

[0018] Furthermore, the blade suction surface 13a is provided with the plurality of grooves 14 extending in the rotation-axis direction AX, that is, in the longitudinal direction of the blade. Each of the grooves 14 having a depressed shape includes a groove bottom 14b and groove sides 14a connected to opposite edges of the groove bottom 14b. Figs. 6 and 7 are cross-sectional views taken in the direction perpendicular to the rotation axis AX of the impeller and is an explanatory diagram illustrating the shape of the grooves 14 provided on the blade suction surface 13a in an enlarged manner. The groove sides 14a are inclined such that the groove width gradually increases from the groove bottom 14b toward the blade suction surface 13a. Furthermore, connection areas between the groove sides 14a and the blade suction surface 13a are rounded so as to be formed into, for example, a substantially circular arc shape. Moreover, connection areas between the groove sides 14a and the groove bottom 14b are rounded so as to be formed into, for example, a substantially circular arc shape. The groove depth of each groove 14 will be defined as h, the groove width will be defined as g, a flat section of the blade suction surface 13a between neighboring grooves 14 will be defined as M, and the length of the flat section will be defined as ML. A dotted line i denotes a blade suction surface 13a in a case where the grooves 14 are not formed thereon. The groove width g and the flat-section length ML are each defined as a distance between imaginary intersection points 14p. Specifically, each imaginary intersection point 14p is an imaginary intersection of extension lines of the blade suction surface 13a and the groove sides 14a.

[0019] Furthermore, as shown in Figs. 5 and 6, a dotted line K is defined as an isopachous line from the blade pressure surface 13b with the blade thickness te1 of the leading edge 15a or the blade thickness te2 of the trailing edge 15b. The groove bottom 14b of each groove 14 is formed on the blade suction surface 13a side with respect to the isopachous line K. Specifically, the grooves 14 are provided on the blade suction surface 13a side with respect to the isopachous line K. Furthermore, the grooves 14 are formed such that the groove depth h of each groove 14 and the flat-section length ML of each flat section M satisfy the following relationship: groove depth h < flat-section length ML. In addition, a groove depth hc in the midsection 15c between the leading edge 15a and the trailing edge 15b is set to be larger than a groove depth ht in areas near the leading edge 15a and the trailing edge 15b.

[0020] With regard to such an impeller 8a having the grooves 14 in the blades 8c, Fig. 8 illustrates the flow of air along the blade suction surface 13a and the blade pressure surface 13b of a single blade 8c when the blade 8c passes through the suction area E1 of the impeller. Fig. 8 is an explanatory diagram illustrating the flow of air when the blade 8c passes through the suction area E1 of the impeller.

When the blade 8c passes through the suction area E1 of the impeller, the suction air travels from the leading edge 15a to the blade suction surface 13a. Since the blade suction surface 13a is provided with the grooves 14 and inside of each groove falls to a negative-pressure, the flow turns into one with directional components traveling toward the interior of the grooves 14, as indicated by arrows 20. Accordingly, as the air flows downstream, even when the airflow is near to being separated from the blade suction surface 13a, the airflow is drawn to the blade suction surface 13a. Because the airflow is drawn to the blade suction surface 13a until the air reaches the trailing edge 15b on the downstream side, a separation vortex created when the flow departs from the trailing edge 15b can be made smaller.

[0021] Fig. 9 is an explanatory diagram illustrating the flow of air along the blade suction surface 13a and the blade pressure surface 13b of a single blade 8c when the blade 8c passes through the discharge area E2 of the impeller. When the blade 8c passes through the discharge area E2 of the impeller, the suction air travels from the trailing edge 15b to the blade suction surface 13a. Since the blade suction surface 13a is provided with the grooves 14 and inside of each groove falls to a negative-pressure, the flow turns into one with directional components traveling toward the interior of the grooves 14, as indicated by arrows 21. Accordingly, as the air flows downstream, even when the airflow is near to being separated from the blade suction surface 13a, the airflow is drawn to the blade suction surface 13a. Because the airflow is drawn to the blade suction surface 13a until the air reaches the leading edge 15a on the downstream side, a separation vortex created when the flow departs from the trailing edge 15b can be made smaller.

[0022] As above, with the grooves 14 provided on the blade suction surface 13a, separation of the airflow from the blade suction surface 13a can be suppressed in both the suction area E1 and the discharge area E2. As a result, a separation vortex created when the flow departs from the leading edge 15a toward the discharge area E2 can be made smaller.

[0023] In addition, since the grooves 14 extend in the rotation-axis direction (the longitudinal direction of the blade), the drawing effect of the grooves 14 can be obtained even when the flow of air traveling in the longitudinal direction varies in air velocity. Therefore, flow separation can be suppressed throughout.

Moreover, since flow separation can be suppressed, effective area of each flow path between the blades can be increased and, thus, motor driving torque can be reduced. Consequently, a highly efficient cross flow fan can be obtained.

[0024] In the cross section taken in the direction perpendicular to the rotation axis, the multiple grooves 14 formed on each blade suction surface 13a of the cross flow fan are separated from each other by a predetermined distance ML so that the flat sections M are provided between neighboring grooves 14. If the grooves 14 were to be continuously formed without any spacing therebetween in the direction of the chord line L, the flow would not be able to reattach itself to the blade suction surface 13a even with generation of negative pressure in the grooves 14, causing the flow to become unstable. Specifically, the drawing effect of the grooves 14 allows the air flowing along the blade suction surface 13a to flow over each groove 14 and then reattach itself to the blade suction surface 13a connected to the groove 14. By configuring the flat sections M to have the length ML between neighboring grooves 14, a sufficient distance is ensured for the reattachment, thereby allowing stable reattachment. Accordingly, by repetition of the "reattachment to the suction surface after exertion of the drawing effect of the groove 14, and then re-exertion of the drawing effect..." the flow becomes constantly stable. This is particularly advantageous in that the drawing effect of the grooves 14 can be sufficiently exhibited. As a result, a low-noise, highly efficient cross flow fan is achieved. In addition, flow separation caused by change in airflow resistance can be prevented, and backflow toward the fan caused by unstable discharge flow can also be prevented.

[0025] In the cross section taken in the direction perpendicular to the rotation axis, the connection areas between the blade suction surface 13a and the groove sides 14a of the multiple grooves 14 formed on the blade suction surface 13a have been rounded so as to be formed into, for example, a substantially circular arc shape. Accordingly, when the air is drawn to each groove 14 while flowing toward the downstream side of the blade suction surface 13a, pressure fluctuations caused by air impeding a corner edge can be prevented. Consequently, a cross flow fan with lower noise and higher efficiency can be obtained. Furthermore, the two corner edges that connect the two groove sides 14a of each groove 14 to the blade suction surface 13a have been both given a substantially circular arc shape. Thus, even when the direction of flow along the blades 8c is reversed in the suction area E1 and the discharge area E2, flow separation can still be suppressed in both the suction area E1 and the discharge area E2.

[0026] Furthermore, in the cross section taken in the direction perpendicular to the rotation axis, each groove bottom 14b is given a rounded shape, and the groove sides 14a continuing from the groove bottom 14b are given a shape that widens toward the blade suction surface 13a. Because the groove bottom 14b has, for example, a circular arc shape, the flow can circulate smoothly within the groove and is stabilized. Moreover, since the groove sides 14a are inclined so as to widen toward the blade suction surface 13a, the flow can be effectively guided into the groove 14, thereby the drawing effect can be obtained. Consequently, a cross flow fan with lower noise and higher efficiency can be obtained.

[0027] Furthermore, the groove bottom 14b of each groove 14 has been formed on the blade suction surface 13a side with respect to the isopachous line K. For example, in a case in which the blade thickness near the leading edge 15a or the trailing edge 15b is about 0.5 mm and the blade thickness at the midsection 15c is about 1.5 mm, the isopachous line K will be located at about 0.5 mm from the blade pressure surface 13b. Because the grooves 14 are formed on the blade suction surface 13a side with respect to the isopachous line K, the groove depth hc in the midsection 15c is configured to be 1.0 mm or smaller. For example, the groove depth h is set to about 0.25 mm and the grooves 14 near the leading edge 15a or the trailing edge 15b are provided in an area of the blade suction surface 13a where the blade thickness is larger than about 0.75 mm. With this configuration, the drawing effect of the grooves 14 can be obtained, and a sufficient thickness of the blades 8c can be ensured even with the formation of the grooves 14, thereby achieving increased strength.

[0028] Furthermore, the grooves 14 are formed such that the following relationship is satisfied: groove depth h < flat-section length ML. Specifically, in the cross section taken in the direction perpendicular to the rotation axis, the multiple grooves 14 formed on each blade suction surface 13a of the cross flow fan are separated from each other by at least the predetermined distance ML in the direction of the chord line. Although the effects of the flat sections M have already been described above, by setting the flat-section length ML larger than the groove depth h, the flat sections M can ensure the reattachment of air after the air flows over the grooves 14, and by repeating this cycle of the drawing effect and the reattachment, the flow is made constantly stable without separating itself from the blade suction surface 13a. Consequently, a low-noise, highly efficient cross flow fan is obtained.

[0029] Although the above-described configuration is provided with the grooves 14 in the entire blade suction surface 13a from the leading edge 15a to the trailing edge 15b, the embodiment is not limited to this configuration. The grooves 14 may alternatively be provided near at least the leading edge 15a or the trailing edge 15b. For example, the configuration may be such that a few, for example, two, grooves 14 are provided near the leading edge 15a, and a few, for example, two, grooves 14 are provided near the trailing edge 15b. As a further alternative, the configuration may be such that a few, for example, two, grooves 14 are provided only near the leading edge 15a, or may be such that a few, for example, two, grooves 14 are provided only near the trailing edge 15b. By at least providing the grooves 14 at the outer blade side 15a, which is the upstream side in the suction area E1, and the inner blade side 15b, which is the upstream side in the discharge area E2, airflow separation can be effectively reduced with the grooves 14.

[0030] Depending on the configuration of the apparatus that is equipped with the cross flow fan 8, if flow separation tends to occur in the suction area E1, it is effective to provide the grooves 14 near the leading edge 15a, which is the upstream side of the flow in the suction area E1. If flow separation tends to occur in the discharge area E2, it is effective to provide the grooves 14 near the trailing edge 15b, which is the upstream side of the flow in the discharge area E2.

However, providing the grooves 14 on the entire blade suction surface 13a from the leading edge 15a to the trailing edge 15b in the cross section taken in the direction perpendicular to the rotation axis, as shown in Figs. 8 and 9, is more effective since flow separation can be prevented at any location of the blade suction surface 13a.

[0031] Although the grooves 14 extending in the rotation-axis direction on the blade suction surface 13a of each blade 8c are long grooves that extend from one end to the other end of the blade 8c in the above description, the grooves 14 may be partially provided on the blade 8c. For example, providing the grooves 14 on at least either one of the midsection, one of the longitudinal ends, or the other one of the longitudinal ends of the blade would offer advantageous effects. Furthermore, the multiple grooves 14 do not necessarily need to have the same length. Moreover, the multiple grooves 14 may be irregularly arranged. Specifically, in the longitudinal direction of the blade 8c, the multiple grooves 14 may have various start positions and end positions depending on each of the grooves 14.

Furthermore, for each groove 14, the groove depth h, the flat-section length ML, and the groove width g do not necessarily need to be the same. For example, the groove width g may change in a gradual or stepwise manner such that it is large at one longitudinal end of the blade and small at the other end.

[0032] By forming the grooves 14 unevenly in the longitudinal direction of the blade instead of forming them evenly, the cross section thereof taken in the direction perpendicular to the rotation axis would vary depending on the location in the longitudinal direction of the blade. Specifically, the number of grooves 14 will vary in the direction of the chord line L if air were to drift onto the blade suction surface 13a. Even if a slight flow separation occurs in the longitudinal direction of the blade, the flow will be affected by the longitudinal flow close by and would be dispersed. Thus, uniform distribution of air velocity is obtained. Consequently, noise is reduced.

[0033] As shown in Fig. 5, the groove depth hc in the midsection of each blade 8c between the leading edge 15a and the trailing edge 15b in the direction of the chord line L is made larger than the groove depth ht on the leading edge 15a side and the trailing edge 15b side and the blade thickness of the blades 8c will not become excessively small. Therefore, the drawing effect of the grooves 14 can be obtained. In addition, misrun during a molding process and strength being insufficient during an assembly process can be prevented, thereby achieving improved productivity.

[0034] Regarding the shape of each blade 8c, if the blade thickness between the blade pressure surface 13a and the blade suction surface 13b were substantially constant, the flow path would gradually become narrow from the trailing edge 15b to the leading edge 15a. In this case, especially when air flows in from the outer circumference side to the inner circumference side in the suction area, the distance between blades increases on the inner circumference side, causing the flow to become unstable. However, by providing the grooves 14, flow separation can be suppressed by the drawing effect. On the other hand, with the blade profile as shown in Fig. 5, the blade suction surface 13a has a smaller arc radius and a larger curvature than the blade pressure surface 13b. Specifically, the blade thickness in the midsection 15c in the direction of the chord line L is larger than the blade thicknesses at the leading edge 15a and the trailing edge 15b. With this shape, a variation in the distance of a flow path between neighboring blades 8c is small from the trailing edges 15b to the leading edges 15a, thus stabilizing the flow when traveling through between the blades. Hence, the grooves 14 are provided on each blade suction surface 13a as in Embodiment 1 so as to suppress the development of a small boundary layer, thereby allowing smooth airflow between the blades and preventing the flow path between the blades from becoming narrow due to turbulence.

[0035] Furthermore, in Embodiment 1, the multiple grooves 14 are arranged substantially parallel to each other in the longitudinal direction of each blade, and are also formed substantially parallel to the leading edge 15a and the trailing edge 15b in the longitudinal direction. Since the drawing effect can be obtained so long as the multiple grooves 14 are formed in the cross section taken in the direction perpendicular to the rotation axis, a similar effect can be obtained even if the grooves 14 are slightly slanted relative to the leading edge 15a and the trailing edge 15b in the longitudinal direction of the blade. For example, the multiple arranged grooves 14 may be formed in a twisted pattern relative to the rotation axis such that the grooves 14 advance or recede in the rotational direction of the impeller 8a.

[0036] As described above, the cross flow fan according to Embodiment 1 includes impeller units including disk-shaped support plates 8b whose center of rotation is located in a center thereof and a plurality of blades 8c extending in a rotation-axis direction and arranged along outer peripheries of the support plates 8b, the blades 8c each being supported by the support plates 8b at opposite ends; an impeller 8a formed by fixing the multiple impeller units 8d in the rotation-axis direction; and a plurality of grooves 14 having a depressed shape that extend in the rotation-axis direction, the grooves 14 being provided on a blade suction surface 13a serving as a back side in a rotational direction of each blade 8c, in which the grooves 14 are separated from each other by a predetermined distance such that a flat section M is provided between neighboring grooves 14. By producing a negative-pressure state in each groove 14, the airflow is drawn to the blade suction surface 13a so that the air flowing over the groove 14 reattaches itself to the blade suction surface 13a, thereby reducing the occurrence of flow separation therefrom. The suppression of flow separation and the suppression of development of a boundary layer on the suction surface side of each blade facilitate increase in the effective area of the flow path between the blades as well as decrease of motor driving torque. Consequently, a low-noise, highly efficient cross flow fan is obtained.

[0037] By installing the cross flow fan 8 described in Embodiment 1 to an air-conditioning apparatus that disposes a cross flow fan 8 between a suction side flow path E1 and a discharge side flow path E2, that disposes a heat exchanger 7 in the suction side flow path E1 so as to surround an impeller 8a, and that exchanges heat in the heat exchanger with the suction air that is to be sent out with a cross flow fan 8 and blows out the air through the discharge side flow path E2 into a room, a quiet, energy-saving air-conditioning apparatus can be obtained. In addition, flow separation is unlikely to occur even if the airflow resistance increases on the upstream side, and a separation vortex caused when the flow departs from each blade 8c can be made smaller with the grooves 14, thus flow is discharged in a stable manner. Hence, during cooling operation of the air-conditioning apparatus, backflow from the room toward the cross flow fan 8 can be prevented, while also preventing dew formed as a result of condensation in the impeller 8a from being released to the outside.

Embodiment 2

[0038] Fig. 10 is a perspective view illustrating the impeller 8a of a cross flow fan according to Embodiment 2 of the invention. Fig. 11 illustrates a part of the impeller on the motor side of the cross flow fan, and includes Fig. 11 (a) showing a partial perspective view of the impeller 8a on the motor side and Fig. 11 (b) is an explanatory diagram showing a side view thereof. Fig. 11 (b) shows a partially cutaway side of the ring 8b located closest to the motor, in which the cutaway area shows the neighboring ring 8b together with the blades 8c. In each of the drawings, reference numerals or characters that are the same as those in Embodiment 1 denote the same components or equivalent components.

[0039] In the impeller 8a according to Embodiment 2, the fan boss 8e fixed to the motor shaft 12a protrudes into the impeller unit 8d located at an end of the impeller 8a. As shown in Fig. 10, the impeller 8a of the cross flow fan 8 has a plurality of impeller units 8d in the rotation-axis direction AX. The impeller units 8d include disk-shaped support plates, for example, rings 8b in this case, whose center of rotation is located in the center thereof, and a plurality of blades 8c extending in the rotation-axis direction and arranged along the outer peripheries of the rings 8b. Opposite ends of the blades 8c are supported by the rings 8b. For example, the impeller units 8d are formed by molding thermoplastic resin, such as AS resin or ABS resin. The impeller 8a is formed by preparing a plurality of, five in this case, impeller units 8d in the rotation-axis direction AX, and then fixing them to each other in the rotation-axis direction AX by, for example, ultrasonic welding. The fan boss 8e is provided at the center of the ring 8b located at the motor-side end, and the fan boss 8e and the motor shaft 12a (shown in Fig. 3) of the motor 12 are fixed to each other at a fixation section 16 by using a screw or the like. By fixing the motor shaft 12a and the rotation shaft of the impeller 8a to each other at the fixation section 16, the impeller 8a is rotationally driven by rotation of the motor 12.

[0040] In Embodiment 2, the fan boss 8e that fixes the impeller 8a and the motor 12 to each other protrudes into the impeller, and the fixation section fixed to the motor shaft 12a is located within an impeller unit 8da. With this configuration, the overall length of the impeller 8a can be increased by the length of the fan boss 8e while maintaining the breadth of the air-conditioning apparatus, thereby improving air-sending characteristics. The impeller unit 8da having this configuration located on the motor-12-side end has an opening C where the blades 8c are partially not provided, so that a fixing member can be inserted when fixing the fan boss 8e and the motor shaft 12a to each other via the threaded hole 16. A circle C in Fig. 11 denotes the opening. For example, the blades 8c are evenly provided 360 degrees around the rotation axis, that is, the shaft, in other impeller units 8d; however, a predetermined number of blades 8c, for example, a single blade in this case, is not provided in an area of the impeller unit 8da that faces the threaded hole 16, such that the threaded hole 16 is exposed through the opening C.

[0041] In Embodiment 2, in the case of the impeller 8a in which the impeller unit 8da partially lacks a blade so as to have the opening C, the grooves 14 shown in Embodiment 1 are at least provided on the blade suction surface 13a of a blade 8ca that is located in an advanced position in the rotational direction relative to the opening C.

[0042] Because the distance between the blade 8ca and a blade 8cb that are next to each other with the opening C therebetween is larger than the distance between the other blades, the amount of airflow is larger than that in flow paths formed between the other blades, thus causing flow separation to occur more easily. When flow separation occurs in the wide flow path formed in the opening C, abnormal flapping sound may be generated. Therefore, in Embodiment 2, the multiple grooves 14 extending in the longitudinal direction of the blade 8c are at least formed on the blade suction surface 13a of the blade 8ca located firstly on the downstream side of the opening C in the rotational direction of the blade 8c. As already described in Embodiment 1, since the flow is drawn by the grooves 14 so that flow separation is suppressed, as shown in Figs. 8 and 9, noise caused by flow separation is reduced compared with a case where the grooves 14 are not formed, whereby a quiet cross flow fan can be obtained.

[0043] The configuration of the grooves 14 is the same as that in Embodiment 1. By at least providing the grooves 14 shown in Embodiment 1 on the blade suction surface 13a of the blade 8ca that is located in an advanced position in the rotational direction relative to the opening C, there is an advantageous effect on the air flowing through between the blades. In addition, by providing the grooves 14 on the blade suction surfaces 13a of the other blades 8c, the occurrence of flow separation between the blades can be further suppressed in the entire impeller. Since flow separation can be suppressed, effective area of each flow path between the blades can be increased and, thus, motor driving torque can be reduced.

[0044] It is further advantageous to provide the grooves 14 not only on the blade suction surface 13a of the blade 8ca that is located in an advanced position in the rotational direction relative to the opening C, but also in a plurality of blades 8c that are located in an advanced position in the rotational direction relative to the opening C, as indicated by an area D. Furthermore, it is even more advantageous to provide the grooves 14 on the blade suction surfaces 13a of a plurality of blades 8c, including the blade 8cb, located in the direction opposite to the rotational direction relative to the opening C.

[0045] Although Fig. 11 illustrates the configuration in which a single blade 8c is not provided so that the fixing member can be inserted into the fixation section 16, the embodiment is not limited to this configuration. For example, there may be a case where the impeller unit 8d is provided with multiple blades 8c at an uneven pitch instead of an even pitch. In that case, by forming the fixation section 16 so that it faces the area with a large pitch, the fixing member can be inserted into the fixation section 16. Accordingly, even in the case where the opening C is formed by partially widening the pitch of the blades 8c so that the fixing member can be inserted into the fixation section 16, multiple grooves 14 extending in the rotation-axis direction AX may at least be provided on the blade suction surface 13a, serving as a trailing surface in the rotational direction RO, of the blade 8c located adjacent to the opening C at the rotational direction RO side of the impeller 8a.

[0046] As described above, the cross flow fan includes impeller units 8d includes disk-shaped support plates 8b whose center of rotation is located in a center thereof and a plurality of blades 8c extending in a rotation-axis direction AX and arranged along outer peripheries of the support plates 8b, the blades 8c each being supported by the support plates 8b at opposite ends; an impeller 8a formed by fixing the multiple impeller units 8d in the rotation-axis direction AX; a motor 12 having a motor shaft 12a that is fixed to the support plate 8b located at an end of the impeller 8a, the motor 12 rotationally driving the impeller 8a; a fixation section 16 for the motor shaft 12a that is located in one of a relevant impeller unit 8d; and an opening C formed by partially widening a pitch of the blades 8c of the impeller units 8d so that a fixing member is insertable into the fixation section 16, in which multiple grooves 14 having a depressed shape and extending in the rotation-axis direction AX are provided on a blade suction surface 13a, which serves as a back side in a rotational direction RO, of at least a blade 8ca located adjacent to the opening C on the rotational-direction RO side of the impeller 8a. Accordingly, flow separation from the blade suction surface 13a is suppressed. Therefore, stable flow is obtained, whereby noise can be reduced.

[0047] Furthermore, as described in Embodiment 1, in the cross section taken in the direction perpendicular to the rotation axis, the grooves 14 may be separated from each other by a predetermined distance so that flat sections M are provided between neighboring grooves. With this configuration, the manufacturing process is facilitated since the fixation section 16 is exposed. In addition, even with the opening C partially provided between the blades, the flow can still be stabilized due to the drawing effect of the grooves 14 and the reattachment effect by the flat sections M, whereby a low-noise, efficient cross flow fan can be obtained.

Furthermore, by installing the cross flow fan in an air-conditioning apparatus, a high quality, quiet air-conditioning apparatus with no discordant noise can be obtained.

[0048] The above description relates to a configuration that suppresses flow separation while taking into account the flow in an area where the distance between neighboring blades is increased due to facilitation of the assembly process related to the fixation section However, the embodiment is not limited to this configuration. In a case where the area where the distance between neighboring blades is provided due to other reasons, the multiple grooves 14 extending in the rotation-axis direction AX may at least be provided on the blade suction surface 13a of the blade 8c located on the rotational-direction side of the area with the increased distance.

Embodiment 3

[0049] Embodiment 3 of the invention will be described below with reference to the drawings. Fig. 12 is a schematic diagram illustrating the impeller 8a of the cross flow fan 8 according to Embodiment 3, and includes Fig. 12 (a) showing a side view of the cross flow fan 8 and Fig. 12(b) showing a cross-sectional view taken along line S-S of Fig. 12(a). A lower half of Fig. 3(b) shows a plurality of blades on the far side of each of the impeller units 8d in a viewable state, whereas an upper half thereof shows a single blade 8c of each of the impeller units 8d. In each of the drawings, reference numerals or characters that are the same as those in Embodiment 1 and Embodiment 2 denote the same components or equivalent components. In Fig. 12(b), a dot-dash line is an imaginary rotation-axis line that indicates the center O of rotation and connects the motor shaft 12a and the fan shaft 8f. As shown in Fig. 12, the impeller 8a of the cross flow fan 8 has a plurality of impeller units 8d in the rotation-axis direction AX. The impeller units 8d include disk-shaped support plates, for example, rings 8b in this case, whose center of rotation is located in the center thereof, and a plurality of blades 8c extending in the rotation-axis direction and arranged along the outer peripheries of the rings 8b. Opposite ends of the blades 8c are supported by the rings 8b. In each impeller unit 8d in Embodiment 3, each of the blades 8c is formed such that a base section (right side in Fig. 12(b)) serving as a connection section where one end is connected to the corresponding ring 8b has the largest cross-sectional shape taken in the direction perpendicular to the rotation axis, and the cross-sectional shape gradually becomes smaller therefrom. Moreover, each blade 8c is tapered such that a tip in the longitudinal direction (left side in Fig. 12(b)) serving as a connection section where the other end is fixed to the adjacent impeller unit 8d has the smallest cross-sectional shape taken in the direction perpendicular to the rotation axis. Specifically, in the cross section taken in the direction perpendicular to the rotation axis, the blade thickness of the blade 8c, which is formed by the blade suction surface 13a and the blade pressure surface 13b, and the blade-chord-line length L1, which is the length of a line that connects the leading edge 15a and the trailing edge 15b, decrease from the base section toward the tip in the longitudinal direction. Therefore, in the cross-sectional view shown in Fig. 12(b), the leading edge 15a and the trailing edge 15b are both slanted toward the inner side of the blade 8c from the base section toward the end in the longitudinal direction. In Embodiment 3, multiple grooves 14 having a depressed shape that extend in the rotation-axis direction AX are provided in the blade suction surface 13a that is a back side in the rotational direction of the blade 8c.

[0050] In the manufacturing process, each impeller unit 8d is formed by molding thermoplastic resin, such as AS resin or ABS resin. Although multiple blades 8c are fixed between two rings 8b in the impeller 8a, each impeller unit 8d is formed by integrally molding the blades 8c with one of the rings 8b, for example, the ring 8b on the motor side. Fig. 13 illustrates how a mold release step is performed in this resin molding process. Fig. 13 is a cross-sectional view of molds 17 and 18. Although Fig. 13 shows a state where one upper blade 8c and one lower blade 8c have been molded, multiple blades 8c are molded while being annularly arranged within the outer periphery of each ring 8b in actuality. The resin molding process involves fabricating the molds 17 and 18 with a concave and convex relief structure in conformity to the shape of the multiple blades 8c, injecting resin into the molds at high pressure, cooling the resin, and moving the mold 18 in the direction of the arrow so that an impeller unit 8d composed of resin is obtained.

[0051] If the molds are to be released in the rotation-axis direction AX, as indicated by the arrow, the impeller unit 8d needs to have a shape that allows the molds to be releasable in the rotation-axis direction AX. Therefore, in the impeller unit 8d, each of the blades 8c is formed such that a base section 8c1, which is where the blade 8c is connected to the ring 8b, has the largest cross-sectional shape, and a longitudinal tip 8c2 has the smallest cross-sectional shape. By giving each blade 8c such a cross-sectional shape, the mold release step during the resin molding process is performed smoothly. In this case, for example, each blade 8c is tapered such that the cross-sectional shape thereof gradually becomes smaller from the base section 8c1 toward the longitudinal tip 8c2 of the blade 8c. The leading edge 15a and the trailing edge 15b are slanted at, for example, about several degrees toward the inner side of the blade 8c. Therefore, when the mold 18 is slightly moved during the mold release step, the mold 18 is released away from the molded impeller unit 8d with a gap formed therebetween over the entire surfaces of the blades 8c, whereby the mold release step is performed readily and smoothly.

[0052] Then, the tapered longitudinal tips 8c2 of the resin-molded impeller unit 8d are fixed to an adjacent ring 8b by, for example, ultrasonic welding, so that the impeller units 8d are fixed to each other in the rotation-axis direction AX, whereby an impeller 8a is formed.

[0053] In Embodiment 3, the grooves 14 similar to those in Embodiment 1 are provided on the blade suction surface 13a of each blade 8c. Specifically, the blade suction surface 13a of the blade 8c is provided with a plurality of grooves 14 having a depressed shape that extend in the longitudinal direction of the blade, which is the rotation-axis direction AX. In the cross section taken in the direction perpendicular to the rotation axis, the multiple grooves 14 arranged at, for example, an even pitch between the leading edge 15a and the trailing edge 15b each have a groove bottom 14b and two groove sides 14a facing each other, and the groove bottom 14b has a rounded shape, such as a substantially circular arc shape. The groove sides 14a extending continuously from the groove bottom 14b widen toward the blade suction surface 13a, and connection areas between the groove sides 14a and the blade suction surface 13 also have a rounded shape. The grooves 14 extending in the rotation-axis direction AX have a shape with protrusions and depressions in the circumferential direction of the impeller 8a but with no protrusions and depressions in the rotation-axis direction AX. Therefore, the grooves 14 have a shape that is suitable for molding each impeller unit 8d in the resin molding process shown in Fig. 13 in which the mold release step is performed in the rotation-axis direction AX.

[0054] The shape of the blades will be further described in detail below. Fig. 14 is a cross-sectional view of one of the blades taken along line A-A in Fig. 12 and shows the cross section of the longitudinal tip 8c2 of the blade 8c. Fig. 15 is a cross-sectional view of one of the blades taken along line B-B in Fig. 12 and shows the cross section of the base section 8c1 of the blade 8c. As shown in Figs. 14 and 15, in the cross section taken in the direction perpendicular to the rotation axis of the cross flow fan, the shape of the blade 8c is the same in any cross section, and the base section 8c1 has maximum dimensions, whereas the longitudinal tip 8c2 has minimum dimensions.

[0055] In Fig. 14 showing the cross section of the longitudinal tip 8c2, the length of the chord line will be defined as L12, the groove depth will be defined as h2, the groove width will be defined as g2, and the maximum blade thickness, which is the diameter of an inscribed circle of the blade pressure surface 13b and the blade suction surface 13a of the blade 8c, will be defined as tmax2. Similarly, in Fig. 15 showing the cross section of the base section 8c1, the length of the chord line will be defined as L11, the groove depth will be defined as h1, the groove width will be defined as g1, and the maximum blade thickness will be defined as tmax1. The definitions of the groove width g and the groove depth h are the same of those shown in Fig. 7 in Embodiment 1. Each blade 8c according to Embodiment 3 has a tapered shape in which the relationships tmax1 > tmax2 and L11 > L12 are satisfied, and the length L1 of the chord line and the maximum thickness tmax gradually decrease from the base section 8c1 toward the longitudinal tip 8c2. With regard to the grooves 14, in the exemplary configuration shown in Fig. 12, multiple grooves 14 having the same shape are provided on the blade suction surface 13a while the relationships h1=h2 and g1=g2 are satisfied.

[0056] Similar to Embodiment 1, when each blade 8c passes through the suction area E1, suction air travels from the leading edge 15a to the blade suction surface 13a. Since the multiple grooves 14 extending in the longitudinal direction of the blade are formed on the blade suction surface 13a, the airflow produced as the suction air travels along the blade suction surface 13a is as shown in Fig. 8. Specifically, a negative-pressure state is produced within the grooves 14, thereby causing the flow to have directional components traveling toward the interior of the grooves 14, as indicated by the arrows 20. Therefore, even when the airflow is near to being separated at the leading edge 15a, the airflow is drawn to the blade suction surface 13a. Moreover, because the airflow is drawn to the blade suction surface 13a until the air reaches the trailing edge 15b on the downstream side, a separation vortex created when the flow departs from the trailing edge 15b can be made smaller.

[0057] Furthermore, as shown in Fig. 9, when the blade 8c passes through the discharge area E2, the suction air travels from the trailing edge 15b to the blade suction surface 13a. Since the blade suction surface 13a is provided with the grooves 14 and inside of each groove falls to a negative-pressure, the flow turns into one with directional components traveling toward the interior of the grooves 14, as indicated by arrows 21. Accordingly, as the air flows downstream, even when the airflow is near to being separated from the blade suction surface 13a, the airflow is drawn to the blade suction surface 13a. Because the airflow is drawn to the blade suction surface 13a until the air reaches the leading edge 15a on the downstream side, a separation vortex created when the flow departs from the trailing edge 15b can be made smaller.

[0058] As above, with the grooves 14 provided on the blade suction surface 13a, separation of the airflow from the blade suction surface 13a can be suppressed in both the suction area E1 and the discharge area E2. As a result, a separation vortex created when the flow departs from the leading edge 15a toward the discharge area E2 can be made smaller.

[0059] In addition, since the grooves 14 extend in the rotation-axis direction AX, the drawing effect of the grooves 14 can be obtained even when variation in air velocity occurs in the longitudinal direction of the blade.

Therefore, flow separation can be suppressed throughout.

Moreover, since flow separation can be suppressed, effective area of each flow path between the blades can be increased and, thus, motor driving torque can be reduced. Consequently, a highly efficient cross flow fan can be obtained.

[0060] Furthermore, similar to Fig. 7 in Embodiment 1, in the cross section taken in the direction perpendicular to the rotation axis, the multiple grooves 14 formed on each blade suction surface 13a of the cross flow fan are separated from each other by a predetermined distance ML so that the flat sections M are provided between neighboring grooves 14. As above, by configuring the flat sections M to have the length ML between neighboring grooves 14, a sufficient distance is ensured for the reattachment, thereby allowing stable reattachment. By repetition of the "reattachment to the suction surface 13a after exertion of the drawing effect of the groove 14, and then re-exertion of the drawing effect..." the flow becomes constantly stable. This is particularly advantageous in that the drawing effect of the grooves 14 can be effectively exhibited. As a result, a low-noise, highly-efficient cross flow fan is achieved. In addition, flow separation caused by change in airflow resistance can be prevented, and backflow toward the fan caused by unstable discharge flow can also be prevented.

[0061] Furthermore, similar to Embodiment 1, in the cross section taken in the direction perpendicular to the rotation axis, the connection areas between the blade suction surface 13a and the groove sides 14a of the multiple grooves 14 formed on the blade suction surface 13a have been rounded so as to be formed into, for example, a substantially circular arc shape. Accordingly, when the air is drawn to each groove 14 while flowing toward the downstream side of the blade suction surface 13a, pressure fluctuations caused by air impeding a corner edge can be prevented. Consequently, a cross flow fan with lower noise and higher efficiency can be obtained. Furthermore, the two corner edges that connect the two groove sides 14a of each groove 14 to the blade suction surface 13a have been both given a substantially circular arc shape. Thus, even when the direction of flow along the blades 8c is reversed in the suction area E1 and the discharge area E2, flow separation can still be suppressed in both the suction area E1 and the discharge area E2.

[0062] Furthermore, similar to Embodiment 1, in the cross section taken in the direction perpendicular to the rotation axis, each groove bottom 14b is given a rounded shape, and the groove sides 14a continuing from the groove bottom 14b are given a shape that widens toward the blade suction surface 13a. Because the groove bottom 14b has, for example, a circular arc shape, the flow can circulate smoothly within the groove and is stabilized. Moreover, since the groove sides 14a are inclined so as to widen toward the blade suction surface 13a, the flow can be effectively guided into the groove 14, thereby the drawing effect can be obtained. Consequently, a cross flow fan with lower noise and higher efficiency can be obtained.

[0063] Furthermore, similar to Embodiment 1, the groove bottom 14b of each groove 14 has been formed on the blade suction surface 13a side with respect to the isopachous line K. With this configuration, the drawing effect of the grooves 14 can be obtained, and a sufficient thickness of the blades 8c can be ensured even with the formation of the grooves 14, thereby achieving increased strength.

[0064] Furthermore, similar to Embodiment 1, the grooves 14 are formed such that the following relationship is satisfied from the base section 8c1 to the longitudinal tip 8c2 in any cross section taken in the direction perpendicular to the rotation axis: groove depth $h <$ flat-section length ML. By setting the flat-section length ML larger than the groove depth h, the flat sections M can ensure the reattachment of air after the air flows over the grooves 14, and by repeating this cycle of the drawing effect and the reattachment, the flow is made constantly stable without separating itself from the blade suction surface 13a. Consequently, a low-noise, highly-efficient cross flow fan is obtained.

[0065] Accordingly, in a cross flow fan with a configuration that allows a simple and smooth mold release step, noise reduction and higher efficiency are achieved. By installing this cross flow fan in an air-conditioning apparatus, a quiet, energy-saving air-conditioning apparatus with good productivity is obtained.

[0066] Fig. 16 is a perspective view illustrating a single blade of another explanatory configuration of the cross flow fan according to Embodiment 3. In this configuration, the groove width g or the groove depth h of each groove 14 is not constant in the longitudinal direction of the blade, but is varied between the base section 8c1 and the longitudinal tip 8c2. Fig. 17 is a partially enlarged cross-sectional view of the longitudinal tip 8c2 of the blade 8c, taken in the direction perpendicular to the rotation axis. Specifically, Fig. 17 is similar to the cross-sectional view taken along line A-A in Fig. 12. The groove width g1 and the groove depth h1 of each groove 14 at the base section 8c1 and the groove width g2 and the groove depth h2 of the groove 14 at the longitudinal tip 8c2 have the following relationships: $g1 < g2$ and $h1 < h2$. Each blade 8c has a tapered shape in which the blade thickness and the length L1 of the chord line gradually decrease from the base section 8c1 at the ring 8b side toward the longitudinal tip 8c2, which is a free end before the fixing process. Moreover, each groove 14 having a depressed shape provided on the blade suction surface 13a is formed such that the groove width g and the groove depth h gradually increase from the base section 8c1 toward the longitudinal tip 8c2.

[0067] Therefore, in addition to the suppression of flow separation owing to the drawing effect of the grooves 14, the drawing effect smoothly changes in the longitudinal direction of the blade (the rotation-axis direction) as the air flows over each groove 14. When the flow is released from the blade 8c, the speed and direction of the flow smoothly change in the longitudinal direction of the blade, so that the speed and angle of flow that comes into contact with the guide wall 10 change especially in the discharge area E2. Because the discharge flow does not reach the guide wall 10 at the same time, pressure fluctuations can be alleviated, thereby achieving further noise reduction.

[0068] Furthermore, when the manufacturing process is performed by a molding method in which the molds 17 and 18 are released away from each other in the rotation-axis direction AX, as shown in Fig. 13, since the leading edge 15a and the trailing edge 15b are slightly slanted in the mold-releasing direction and the entire depression constituting each groove 14 is slightly slanted in the mold-releasing direction, the entire blade 8c including the grooves 14 can be readily released during the resin molding process.

[0069] As a result, further noise reduction and higher efficiency can be achieved in the cross flow fan while maintaining productivity. In addition, flow separation caused by a change in airflow resistance can be prevented so that stable discharge flow can be achieved, thereby achieving a low-noise, highly-efficient cross flow fan.

[0070] In the longitudinal direction of the impeller units 8d, each blade 8c has a tapered shape in which the blade thickness and the length L1 of the chord line gradually decrease from the base section 8c1 on the ring 8b side toward the longitudinal tip 8c2, which is a free end before the fixing process, such that the cross-sectional shape of the blade 8c, taken in the direction perpendicular to the rotation-axis direction, gradually becomes smaller. Alternatively, for example, instead of gradually varying the cross-sectional shape of the blade 8c by giving it a slanted shape, the cross-sectional shape thereof may be varied in a stepwise manner. Even with this configuration in which the cross-sectional shape is varied in a stepwise manner, when the mold 18 is slightly moved during the mold release step, as in the configuration in which the shape is gradually varied, the mold 18 is released away from a molded impeller unit 8d with a gap formed therebetween over the entire surface of the impeller unit 8d whereby the mold release step is performed readily and smoothly.

[0071] Furthermore, the groove width g and the groove depth h of each groove 14 formed on the blade suction surface 13a does not necessarily need to be increased gradually from the base section 8c1 side toward the longitudinal tip 8c2. Specifically, at least the groove width g or the groove depth h of the groove 14 may be increased in a gradual or stepwise manner. In the longitudinal direction of the blade, at least the groove width g or the groove depth h may be increased in a gradual or stepwise manner. Even with the grooves 14 whose depressed shape changes in a stepwise manner, the drawing effect changes in the longitudinal direction of the blade as the air flows over each groove 14. When the flow is released from the blade 8c, the speed and direction of the flow change in the longitudinal direction of the blade. Consequently, since the speed and angle of the discharge flow change when coming into contact with the guide wall 10 especially in the discharge area E2, the discharge flow does not reach the guide wall 10 at the same time. As such, pressure fluctuations can be alleviated and further noise reduction can be achieved.

[0072] Furthermore, the groove depth ht on the leading edge 15a side and the trailing edge 15b side may be made smaller than the groove depth hc in around the midsection 15c that is between the leading edge 15a and the trailing edge 15b of the blade 8c in the direction of the chord line L in Fig. 17. In this case, the blade 8c would not be extremely thin even with the formation of the grooves 14 on the blade suction surface 13a. Thus, misrun during the molding process and strength being insufficient during the assembly process can be prevented, thereby improved productivity can be achieved.

[0073] Furthermore, even in the case where the groove width g and the groove depth h of each groove 14 are varied between the base section 8c1 and the longitudinal tip 8c2, as shown in Fig. 16, the cross-sectional shape of the groove 14 taken in the direction perpendicular to the rotation axis is the same as that in Embodiment 1. Specifically, by designing the flat sections M, the shape of the groove sides 14a, the corner edges between the groove sides 14a and the blade suction surface 13a, and the shape of the groove bottoms 14b in a similar manner to those in Embodiment 1, further noise reduction can be achieved, whereby an efficient cross flow fan can be obtained.

[0074] Fig. 18 illustrates another explanatory configuration of the cross flow fan according to Embodiment 3 and is a front view of one of blades 8c. In this configuration, three grooves 14, for example, are provided only on the outer side of the blade suction surface 13a where the leading edge 15a is located. The shape of a single groove 14 is the same as that in Fig. 17.

In this configuration in which the grooves 14 are provided only on the outer side of the blade, since the drawing effect of the grooves 14 is obtained at the leading edge 15a where flow separation first occur in the suction area E1, flow separation can be suppressed in the suction area E1 so that the flow is stabilized, thereby preventing flow separation in the discharge area E2. Consequently, a quiet, energy-saving cross flow fan can be obtained.

Furthermore, multiple grooves 14 may also be provided on the trailing edge 15b side in addition to the leading edge 15a side. Specifically, multiple grooves 14 may be provided on the outer side and the inner side of the blade 8c but not in the midsection thereof. In a configuration in which the grooves 14 are provided on the trailing edge 15b side, flow separation can be advantageously suppressed particularly in the discharge area E2. By providing multiple grooves 14 extending in the rotation-axis direction AX on at least the leading edge 15a side or the trailing edge 15b side of the blade suction surface 13a, a drawing effect can be obtained to a certain degree.

[0075] As described in Embodiment 1, depending on the configuration of the apparatus that is equipped with the cross flow fan 8, if flow separation tends to occur in the suction area E1, it is effective to provide the grooves 14 near the leading edge 15a, which is the upstream side of the flow in the suction area E1. If flow separation tends to occur in the discharge area E2, it is effective to provide the grooves 14 near the trailing edge 15b, which is the upstream side of the flow in the discharge area E2. However, providing the grooves 14 in the entire blade suction surface 13a from the leading edge 15a to the trailing edge 15b in the cross section taken in the direction perpendicular to the rotation axis, as shown in Figs. 8 and 9, is more effective since flow separation can be prevented at any location of the blade suction surface 13a.

[0076] The grooves 14 provided on the blade suction surface 13a described above extend from the base section 8c1 to the longitudinal tip 8c2, and the grooves 14 all have the same length. Configuration examples in which the grooves 14 have different lengths will be described here. Fig. 19 illustrates another explanatory configuration of the cross flow fan according to Embodiment 3 and is a front view of one of blades 8c. In this configuration, multiple grooves 14 are provided on the longitudinal tip 8c2 side of the blade suction surface 13a but not on the base section 8c1 side. The shape of a single groove 14 is the same as that in Fig. 15, meaning that at least the groove depth h or the groove width g of the groove 14 increases from the base section 8c1 toward the longitudinal tip 8c2.

[0077] In the case where the blade 8c is tapered, the longitudinal tip 8c2 side has a small blade thickness and a short blade-chord-line length L1. Therefore, as compared with the base section 8c1 side, flow separation tends to occur since the distance between the blade suction surface 13a and the neighboring blade pressure surface 13b is large. By at least forming the grooves 14 on the longitudinal tip 8c2 side, flow separation can be suppressed owing to the drawing effect by the negative-pressure state in the grooves 14, thereby achieving noise reduction.

[0078] Furthermore, the multiple grooves 14 formed on the blade suction surface 13a have different lengths J, in the longitudinal direction of the blade 8c, that are varied in a gradual manner. With an end of each groove 14 on the base section 8c1 side being defined as a groove-side end 14c, the grooves 14 are formed such that the groove-side ends 14c of the grooves 14 are arranged slantwise relative to the rotation axis of the impeller. Therefore, the lengths J of the grooves 14 in the longitudinal direction gradually increase in the circumferential direction of the rings 8b. In the configuration shown in Fig. 19, the grooves 14 are formed such that the lengths J thereof gradually increase in a slantwise manner from the leading edge 15a toward the trailing edge 15b.

[0079] Because the number of grooves 14 in the direction of the chord line varies depending on the location in the longitudinal direction of the blade, the airflow shown in Fig. 7 would vary in the suction area E1 depending on the location in the longitudinal direction of the blade. In the case where the cross flow fan is installed in, for example, an air-conditioning apparatus, the suction flow may sometimes drift in the suction area E1 due to the effect of a resistive element in the longitudinal direction of the blade. Even when the suction flow drifts, the drawing effect changes more gradually in the longitudinal direction of the blade in the configuration shown in Fig. 19. Therefore, uniform distribution of air velocity can be achieved, and a local increase in air velocity on the blade surface can be suppressed, thereby stabilizing the flow and achieving noise reduction.

[0080] Fig. 20 illustrates another explanatory configuration of the cross flow fan according to Embodiment 3 and is a front view of one of blades 8c. In this explanatory configuration, the grooves 14 are formed such that the lengths J thereof gradually decrease in a slantwise manner from the leading edge 15a toward the trailing edge 15b. Similar to Fig. 19, with the grooves 14 having this configuration, the drawing effect changes more gradually in the longitudinal direction of the blade even when the suction flow drifts in the suction area E1 due to the effect of a resistive element in the longitudinal direction of the blade. Therefore, uniform distribution of air velocity can be achieved, and a local increase in air velocity on the blade surface can be suppressed, thereby achieving stable flow and noise reduction.

[0081] Furthermore, in the configurations shown in Figs. 19 and 20, the speed and angle of flow when coming into contact with the guide wall 10 change gradually in the longitudinal direction of the blade, so that pressure fluctuations can be alleviated, thereby achieving further noise reduction.

[0082] Fig. 21 illustrates another explanatory configuration. The lengths J of the grooves 14 gradually increase from the leading edge 15a toward the trailing edge 15b up to the midsection, and gradually decrease from the midsection toward the trailing edge 15b. With a configuration as such, the drawing effect changes more gradually in the longitudinal direction of the blade even when the suction flow drifts in the suction area E1 due to the effect of a resistive element in the longitudinal direction of the blade. Therefore, uniform distribution of air velocity can be achieved, and a local increase in air velocity on the blade surface can be suppressed, thereby noise reduction can be achieved. Moreover, in the discharge area E2, the discharge flow changes gradually in the longitudinal direction of the blade, and the velocity and angle of flow when coming into contact with the guide wall 10 change gradually in the longitudinal direction of the blade. Therefore, pressure fluctuations can be alleviated, thereby achieving further noise reduction.

[0083] Furthermore, in the configuration shown in Fig. 21, the grooves 14 are reduced in length in areas of the leading edge 15a and the trailing edge 15b where the blade thickness is small, whereas the grooves 14 are increased in length in an area near the midsection, in the direction of the chord line L, where the blade thickness is large. Therefore, the overall strength of each blade 8c is sufficiently ensured so that buckling can be prevented when fixing the impeller units 8d to each other by, for example, ultrasonic welding.

As a result, with this cross flow fan, further noise reduction can be achieved, and sufficient strength can be ensured when assembling the impeller, thereby preventing losses occurring in the assembly process. By installing this cross flow fan in an air-conditioning apparatus, a quiet air-conditioning apparatus with good productivity is obtained.

[0084] Fig. 22 illustrates another explanatory configuration. In this configuration, the multiple grooves 14 formed in the blade suction surface 13a have different lengths J, in the longitudinal direction of each blade, that are irregularly varied. In this case, the number of grooves 14 in the direction of the blade chord line L varies depending on the location in the longitudinal direction of the blade. Therefore, when the flow drifts in the suction area E1 and slight flow separation is about to occur in the longitudinal direction of the blade, the flow is dispersed by the flow close by. Thus, uniform wind-speed distribution can be achieved, thereby achieving noise reduction. Furthermore, even when the air drifts on the upstream side of the cross-flow fan due to, for example, dust accumulated in the filter 5, flow separation can be prevented, thereby stabilizing the suction flow. The same applies to the discharge area E2. Specifically, the discharge flow will vary irregularly in the longitudinal direction of the blade, and the speed and angle of the discharge flow will change irregularly when the discharge flow comes into contact with the guide wall 10. Therefore, pressure fluctuations can be irregularly alleviated, thereby achieving noise reduction.

With regard to the grooves 14 having a depressed shape provided in the blade suction surface 13a, it is effective to provide the grooves 14 at locations where flow separation is expected to occur in accordance with conditions in which the cross-flow fan operates.

[0085] As described above, the cross flow fan includes impeller units including disk-shaped support plates 8b whose center of rotation is located in a center thereof and a plurality of blades 8c extending in a rotation-axis direction and arranged along outer peripheries of the support plates 8b, the blades 8c each being supported by the support plates 8b at opposite ends; an impeller 8a formed by fixing the multiple impeller units 8d in the rotation-axis direction. A cross-sectional shape, taken in a direction perpendicular to the rotation axis, of one end of each blade 8c that is a connection section 8c1 connected to the relevant support plate 8b is larger than a cross-sectional shape, taken in the direction perpendicular to the rotation axis, of the other end of each blade 8c that is a connection section connected to a relevant support plate 8b and multiple grooves 14 having a depressed shape and extending in the rotation-axis direction are provided in a blade suction surface 13a serving as a back side in a rotational direction of the blade 8c. Consequently, a low-noise cross flow fan can be obtained while maintaining productivity. Moreover, backflow toward the fan caused by unstable discharge flow can also be prevented. In addition, flow separation is unlikely to occur at the blade suction surface 13a even if the airflow resistance increases, thereby stabilizing the discharge flow.

[0086] In each of Figs. 18 to 22, although a configuration in which at least the groove width g or the groove depth h of each groove 14 is larger on the longitudinal tip 8c2 side than on the base section 8c1 side has been described, the invention is not limited to this configuration. Alternatively, the grooves 14 may each have a constant groove width g and a constant groove depth h so long as the molds are released in a direction other than the rotational direction of the impeller in the resin molding process. Moreover, although the groove length is varied with reference to the longitudinal tip 8c2 in view of the fact that the molds are to be released in the rotational direction of the impeller in the resin molding process, the groove length may be varied with reference to the base section 8c1 or with reference to either the longitudinal tip 8c2 or the base section 8c1 if the molds are to be released in other directions. As a further alternative, grooves with irregular lengths may be provided at irregular positions. By providing the blade suction surface 13a with the grooves 14 that extend at least in the rotation-axis direction AX and that are separated from each other by a predetermined distance so that flat sections M are provided between neighboring grooves 14, flow that tends to separate itself from the blade suction surface 13a can be drawn back thereto by the grooves 14, whereby stable flow can be obtained.

[0087] Furthermore, similar advantages can be achieved by applying the configuration of the grooves 14 having various groove widths G, various groove depths h, or various groove lengths J, as in each of Figs. 16 to 22, to each blade 8c in Embodiment 1 that does not have a tapered shape. Likewise, similar advantages can be achieved by applying the aforementioned configuration to Embodiment 2.

[0088] In particular, as shown in Fig. 2, since multiple resistive elements with different sizes and different airflow resistances, such as the electrostatic precipitator 6, the filter 5, and the air inlet 2 at the upper side of the air-conditioning apparatus body, are unevenly arranged in the air-conditioning apparatus, when the blades 8c pass through the suction area E1 on the heat exchanger 7 side, the air velocity of the suction flow varies. Moreover, flow separation tends to occur easily when the attack angle of the flow against the blades changes due to an increase in airflow resistance caused by dust adhered to the filter disposed at the suction side of the impeller. This causes the discharge flow to become unstable and travel back toward the fan, possibly dampening the floor if dew, which is formed as a result of condensation in the impeller during cooling operation, is released to the outside. By installing the cross flow fan according to any one of Embodiment 1 to Embodiment 3 in the air-conditioning apparatus, stable flow can be obtained, thereby achieving noise reduction and higher efficiency. In addition, flow separation caused by a change in airflow resistance is prevented, and backflow toward the fan caused by unstable discharge flow is prevented, whereby a quiet, high-quality air-conditioning apparatus can be obtained.

[0089] According to Embodiment 1 to Embodiment 3, since multiple grooves extending in the rotation-axis direction AX are formed in each blade suction surface 13a of the impeller of the cross flow fan, stable airflow can be achieved, whereby a low-noise, quiet, highly-efficient, energy-saving cross flow fan can be obtained. In addition, by installing this cross flow fan in an air-conditioning apparatus, stable airflow can be achieved, and dew formed as a result of condensation in the impeller during cooling operation can be prevented from being released to the outside, whereby a high-quality air-conditioning apparatus can be obtained.

[0090] Furthermore, although explanatory configurations in which the cross flow fan is installed in, for example, an air-conditioning apparatus are described in Embodiment 1 to Embodiment 3, the invention is not limited to these explanatory configurations. For example, the cross flow fan may be installed in other types of apparatuses, such as an air curtain. By using a low-noise cross flow fan, noise from an apparatus equipped with this cross flow fan can advantageously be reduced.

Reference Signs List

[0091] 1 air-conditioning apparatus body; 2 air inlet; 3 air outlet; 7 heat exchanger; 8 cross flow fan; 8a impeller; 8b support plate; 8c blade; 8c1 base section; 8c2 longitudinal tip; 8d impeller unit; 9 stabilizer; 10 guide wall; 12 motor; 12a motor shaft; 13a blade suction surface; 13b blade pressure surface; 14 groove; 14a groove side; 14b groove bottom; 14P imaginary intersection point; 15a leading edge; 15b trailing edge; 16 fixation section; C opening; E1 suction area; E2 discharge area; L chord line; L1 length of chord line L; L11 blade-chord-line length of base section 8c1; L12 blade-chord-line length of longitudinal tip 8c2; M flat section; ML flat-section length; O center of rotation; RO rotational direction; g groove width; g1 groove width at base section 8c1; g2 groove width at longitudinal tip 8c2; h groove depth; h1 groove depth at base section 8c1; h2 groove depth at longitudinal tip 8c2; ht groove depth in areas near leading edge 15a and trailing edge 15b; hc groove depth in midsection and vicinity thereof in direction of chord line; K isopachous line of thickness at leading edge or trailing edge with reference to blade pressure surface; tmax maximum thickness of blade; tmax1 maximum thickness at base section 8c1; tmax2 maximum thickness at longitudinal tip 8c2.

Claims

1. A cross flow fan comprising:

impeller units including
disk-shaped support plates whose center of rotation is located in a center thereof and
a plurality of blades extending in a rotation-axis direction and arranged along outer peripheries of the support plates, the blades each being supported by the support plates at opposite ends;
an impeller formed by fixing the impeller units in the rotation-axis direction; and
a plurality of grooves having a depressed shape that extend in the rotation-axis direction, the grooves being provided on a blade suction surface serving as a back side in a rotational direction of each blade, wherein
the grooves are separated from each other by a predetermined distance such that a flat section is provided between neighboring grooves.

2. A cross flow fan comprising:

impeller units including
disk-shaped support plates whose center of rotation is located in a center thereof and
a plurality of blades extending in a rotation-axis direction and arranged along outer peripheries of the support plates, the blades each being supported by the support plates at opposite ends;
an impeller formed by fixing the impeller units in the rotation-axis direction;
a motor having a motor shaft that is fixed to the support plate located at an end of the impeller, the motor rotationally driving the impeller;
a fixation section for the motor shaft that is located in one of a relevant impeller unit; and
an opening formed by partially widening a pitch of the blades of the impeller units so that a fixing member is insertable into the fixation section, wherein
a plurality of grooves having a depressed shape and extending in the rotation-axis direction are provided on a blade suction surface serving as a back side in a rotational direction of at least a blade located adjacent to the opening on the rotational-direction side of the impeller.

3. A cross flow fan comprising:

impeller units including
disk-shaped support plates whose center of rotation is located in a center thereof and
a plurality of blades extending in a rotation-axis direction and arranged along outer peripheries of the support plates, the blades each being supported by the support plates at opposite ends;

and
an impeller formed by fixing the impeller units in the rotation-axis direction, wherein
a cross-sectional shape, taken in a direction perpendicular to the rotation axis, of one end of each blade that is a connection section connected to an associated support plate is larger than a cross-sectional shape, taken in the direction perpendicular to the rotation axis, of the other end of each blade that is a connection section connected to an associated support plate, and
a plurality grooves having a depressed shape and extending in the rotation-axis direction are provided in a blade suction surface serving as a back side in a rotational direction of the blade.

4. The cross flow fan of claim 3, wherein the grooves extending in the rotation-axis direction are provided on the blade suction surface on at least the connection section side of the other end.

5. The cross flow fan of claim 2, 3 or 4, wherein, in a cross section taken in the direction perpendicular to the rotation axis, the grooves are separated from each other by a predetermined distance such that a flat section is provided between neighboring grooves.

6. The cross flow fan of claim 1 or 5, wherein, in a cross section taken in the direction perpendicular to the rotation axis, the distance between the neighboring grooves is larger than a groove depth of each groove having the depressed shape.

7. The cross flow fan of any one of claims 1 to 6, wherein, in a cross section taken in the direction perpendicular to the rotation axis, each of the grooves having the depressed shape includes a groove bottom and groove sides that face each other, and connection areas between the groove sides and the blade suction surface have a rounded shape.

8. The cross flow fan of any one of claims 1 to 7, wherein, in a cross section taken in the direction perpendicular to the rotation axis, each of the grooves having the depressed shape includes the groove bottom and the groove sides that face each other, the groove bottom has a rounded shape, and the groove sides continuously extending from the groove bottom have a shape that widens toward the blade suction surface.

9. The cross flow fan of any one of claims 1 to 8, wherein, in a cross section taken in the direction perpendicular to the rotation axis, the blades each have a substantially circular-arc shape between a leading edge located on an outer circumference side of the support plates and a trailing edge located on an inner circumference side of the support plates, a blade thickness of a midsection between the leading edge and the trailing edge is larger than blade thicknesses at the leading edge and the trailing edge, and the grooves having the depressed shape provided on the blade suction surface are disposed so as to have at least a distance equivalent to the blade thickness of the leading edge or the trailing edge from a blade pressure surface serving as a leading surface in the rotational direction of the blade.

10. The cross flow fan of any one of claims 1 to 9, wherein, in a cross section taken in the direction perpendicular to the rotation axis, the blades each have a substantially circular-arc shape between the leading edge located on the outer circumference side of the support plates and the trailing edge located on the inner circumference side of the support plates, and the grooves are provided near at least the leading edge or the trailing edge.

11. The cross flow fan of any one of claims 1 to 10, wherein, in a cross section taken in the direction perpendicular to the rotation axis, at least a groove width or a groove depth of each groove having the depressed shape increases or decreases in the rotation-axis direction.

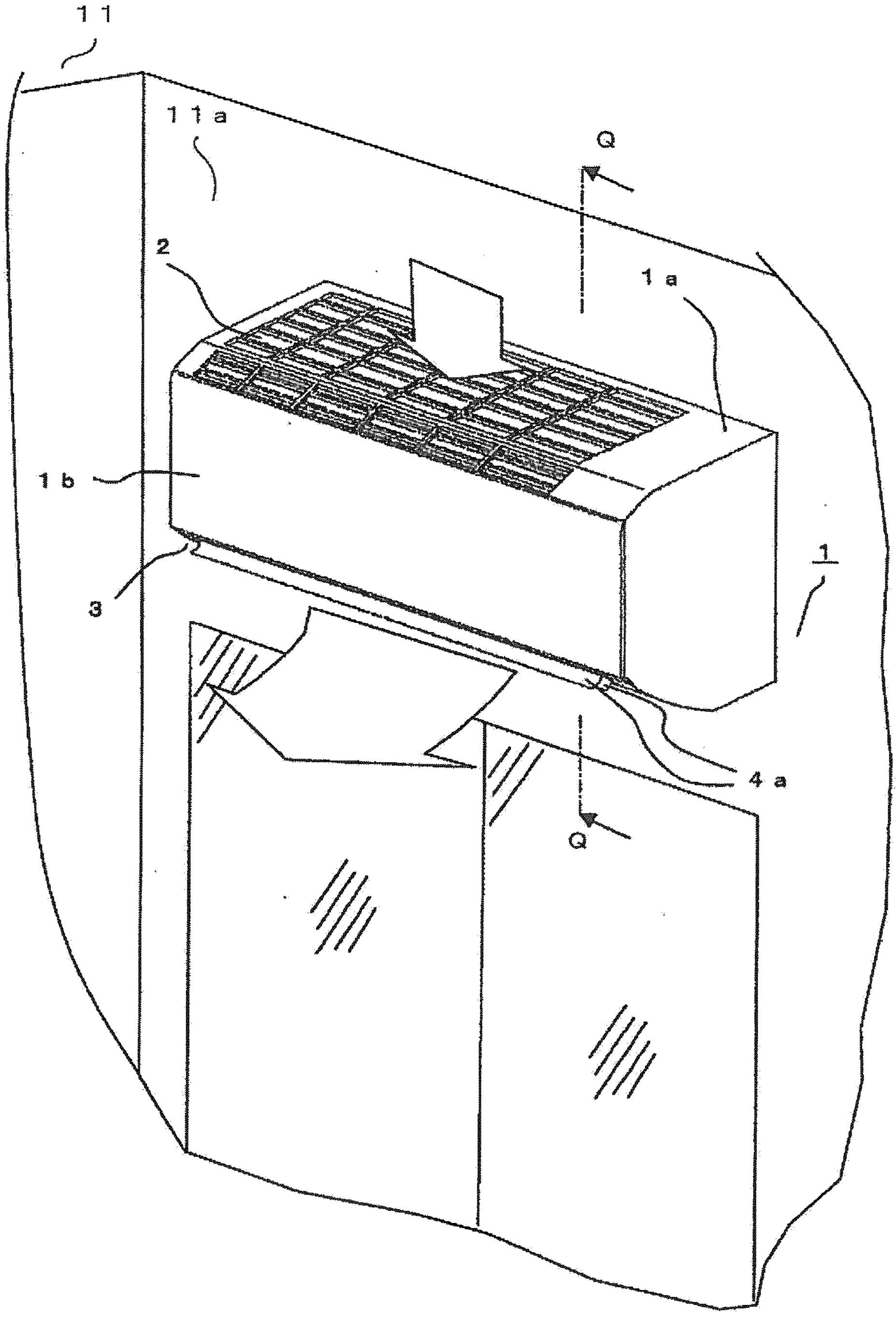
12. The cross flow fan of any one of claims 1 to 11, wherein at least one or some of the grooves formed on the blade suction surface have lengths that are irregularly varied in the rotation-axis direction.

13. The cross flow fan of any one of claims 1 to 11, wherein at least one or some of the grooves formed on the blade suction surface have various lengths, in the rotation-axis direction, that gradually increase or decrease in a circumferential direction of the support plates.

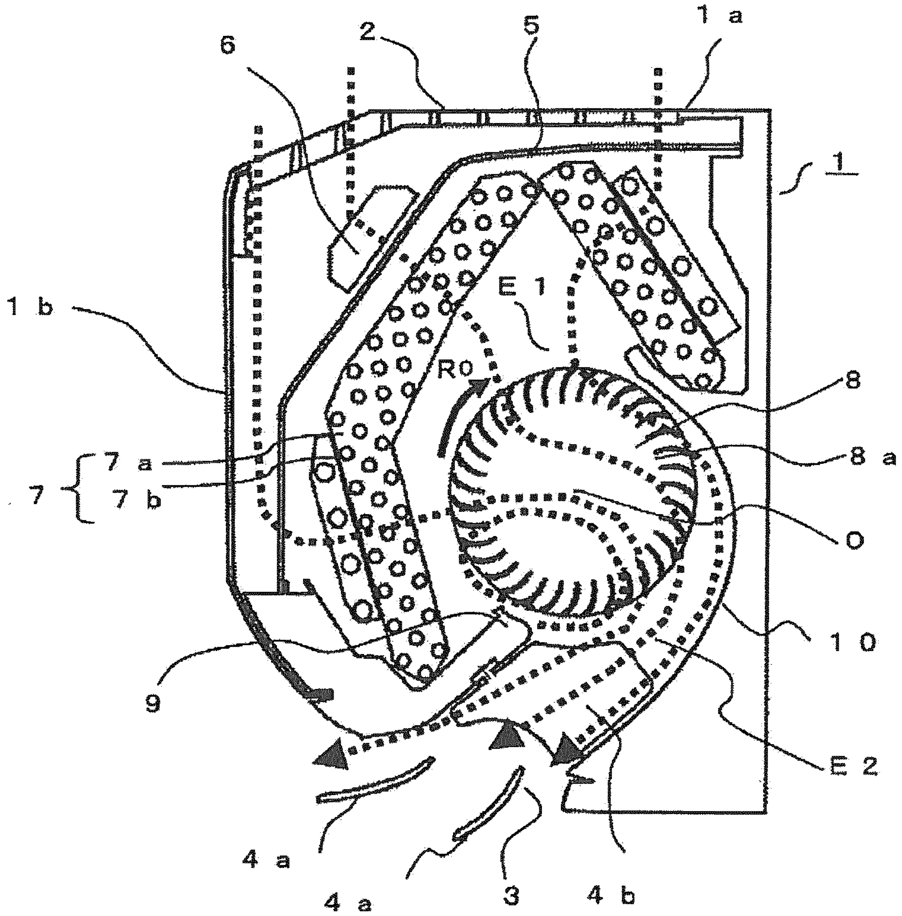
14. The cross flow fan of any one of claims 1 to 13, wherein, in a cross section taken in the direction perpendicular to the rotation axis, the blades each have a substantially circular-arc shape between the leading edge located on the outer circumference side of the support plates and the trailing edge located on the inner circumference side of the support plates, and the groove depth of each of the grooves having the depressed shape formed on the blade suction surface is larger in the midsection, which is located between the leading edge and the trailing edge, than the groove depth in areas near the leading edge and the trailing edge.

15. An air-conditioning apparatus comprising the cross flow fan of any one of claims 1 to 14 and a heat exchanger that is disposed in a suction side flow path formed by the cross flow fan and that performs heat exchange with suction air.

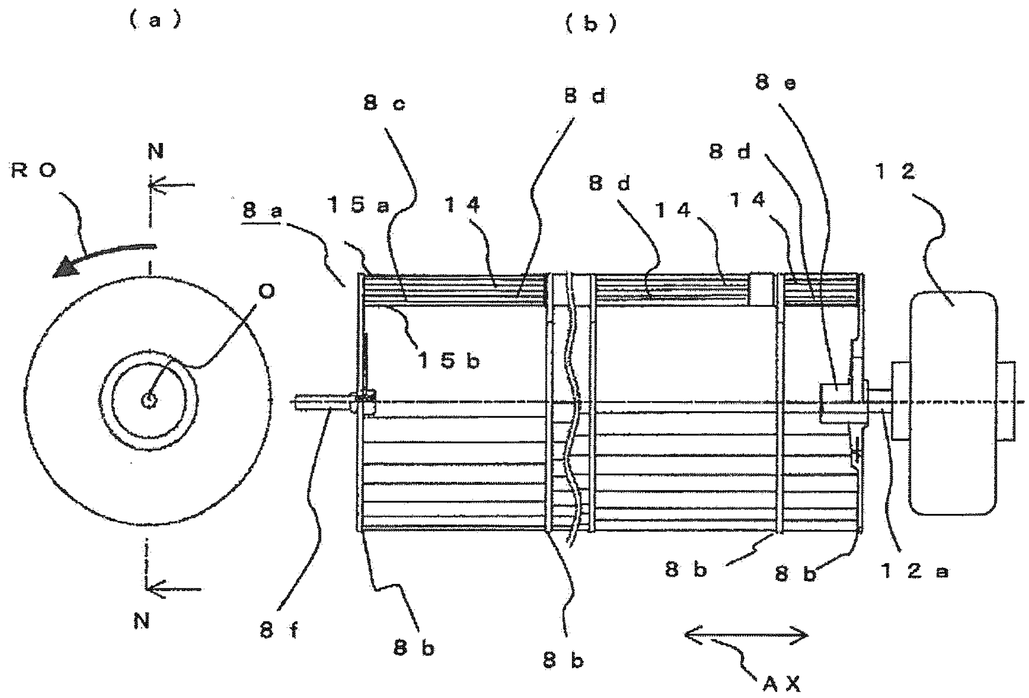
ＦＩＧ．１



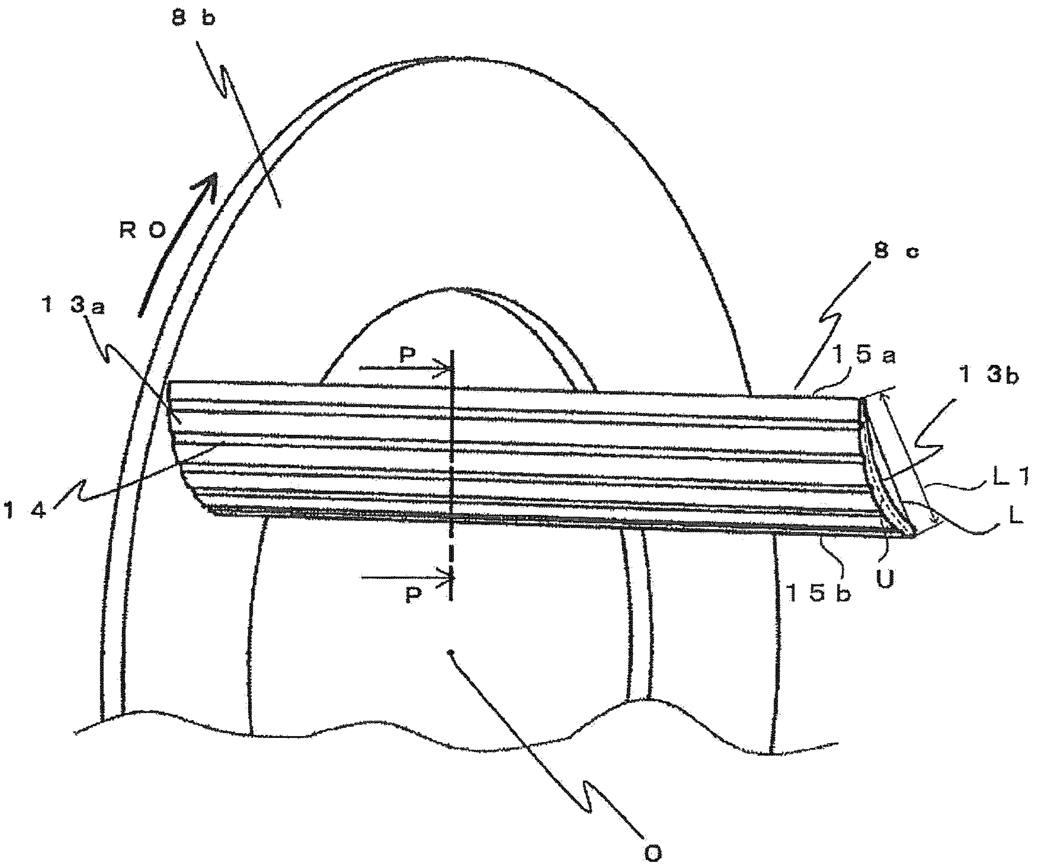
F I G. 2



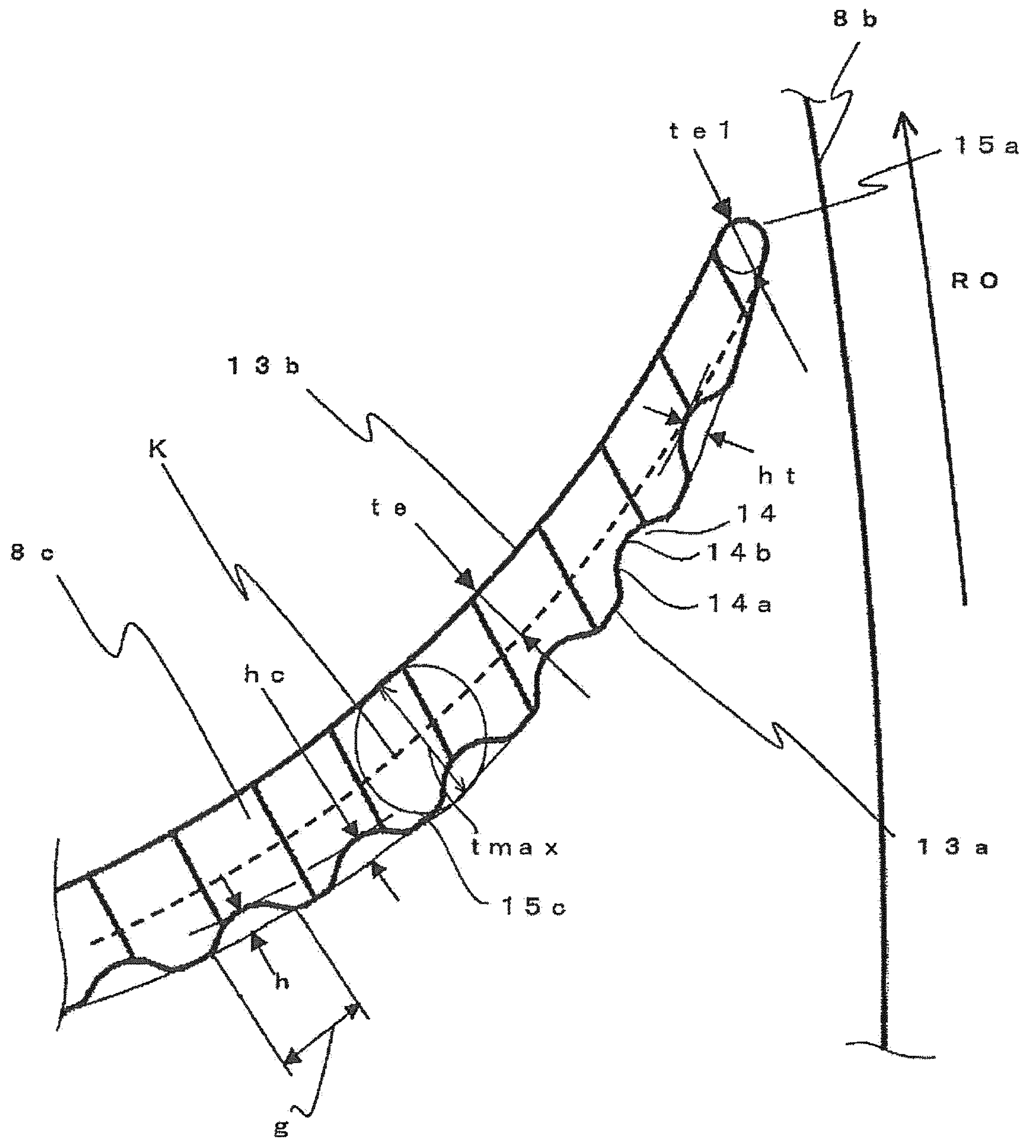
F I G. 3



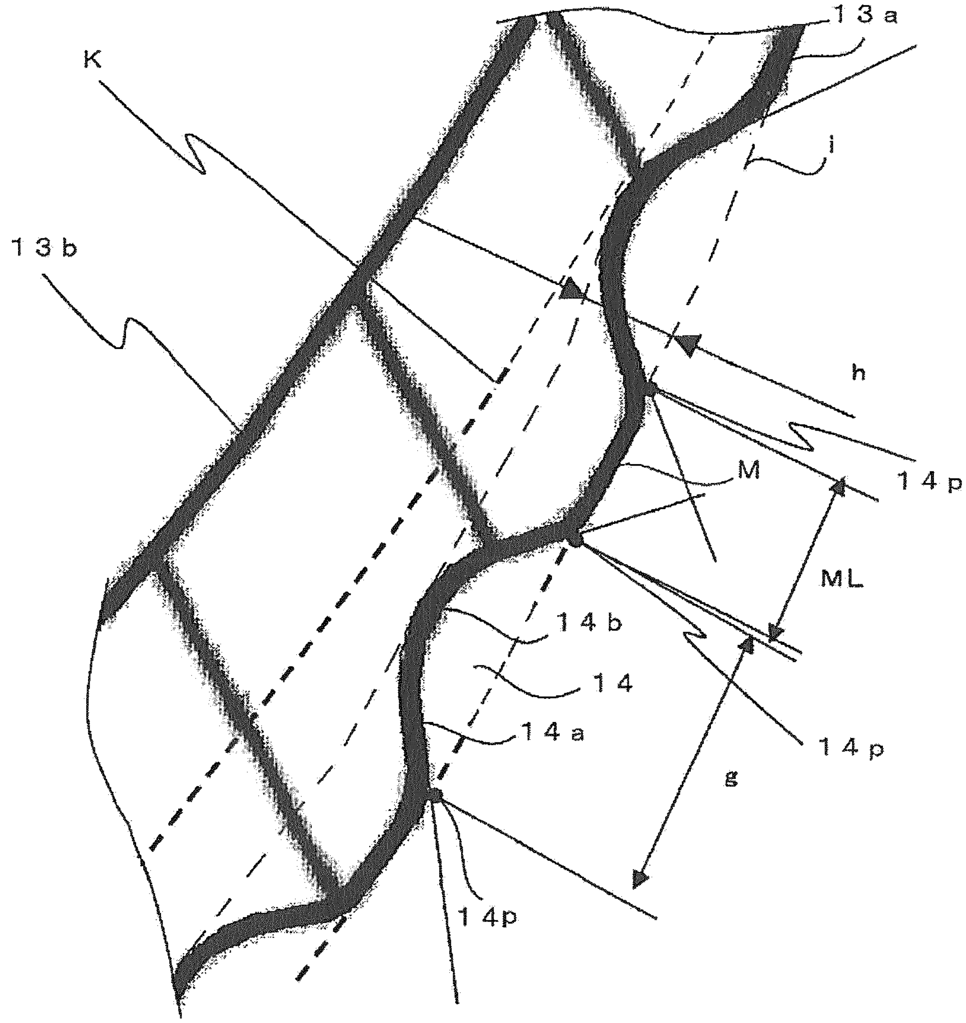
F I G. 4



ＦＩＧ．５



F I G. 6



ＦＩＧ．７

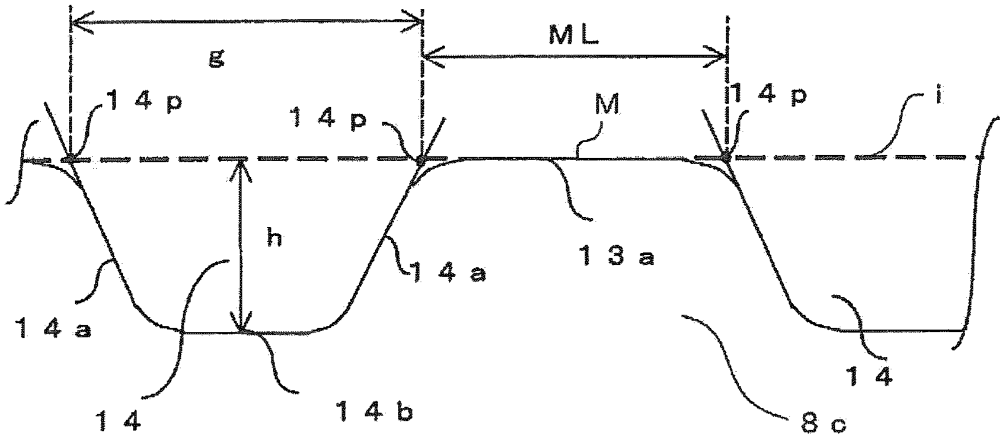


FIG. 8

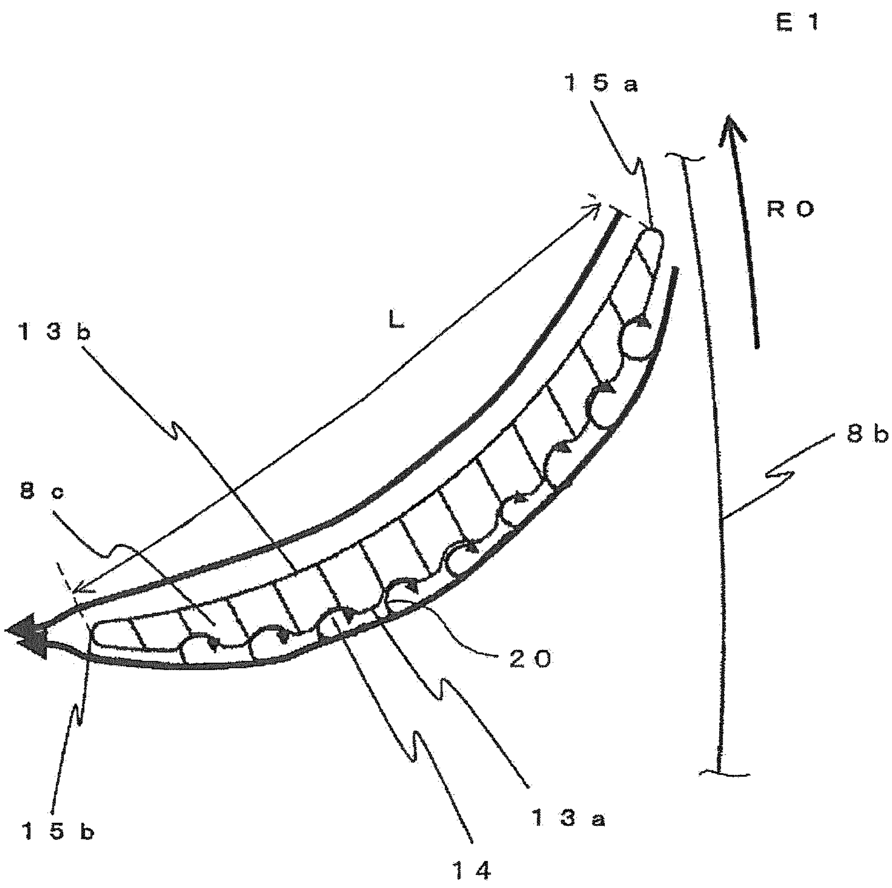
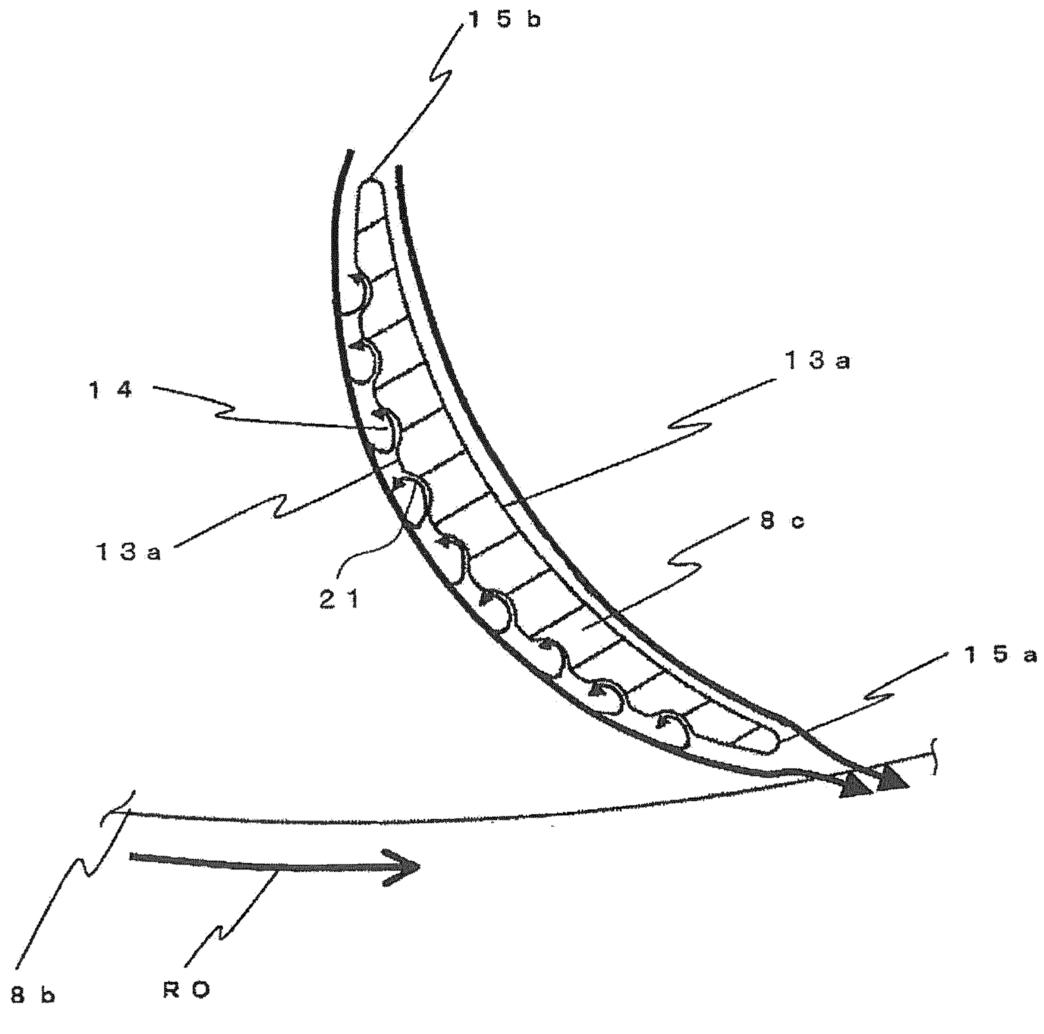


FIG. 9



F I G. 1 0

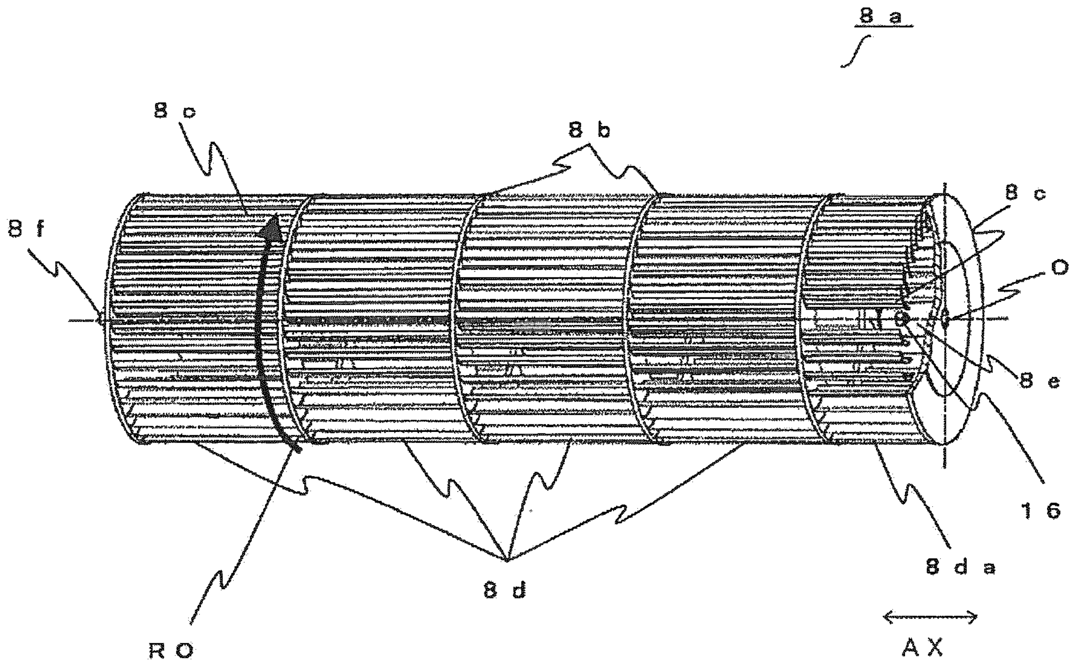
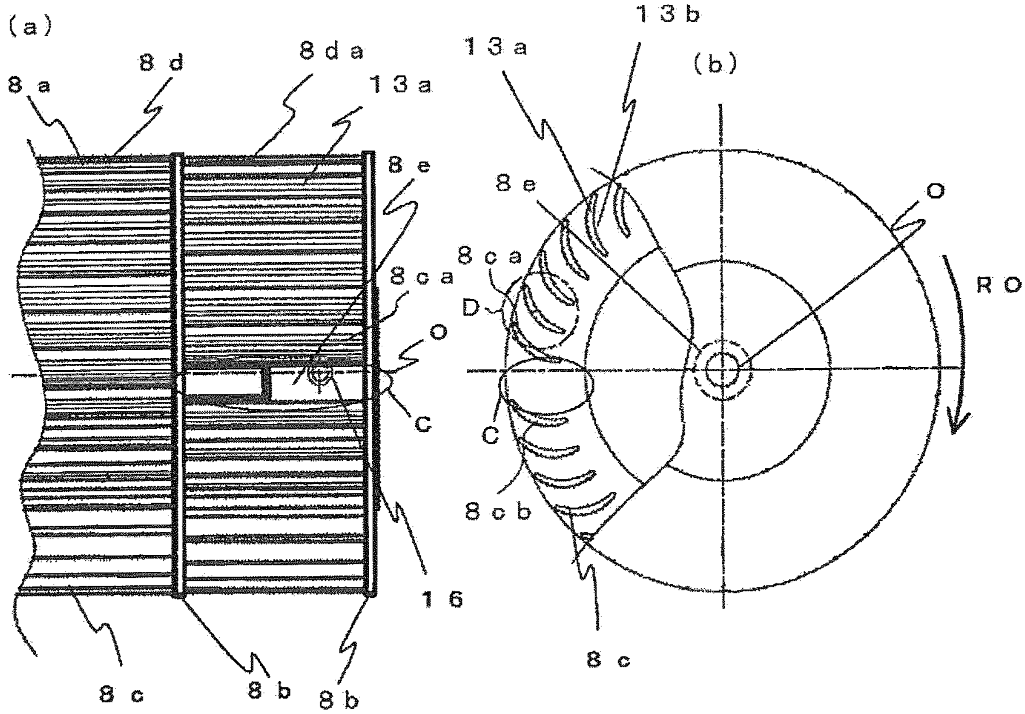
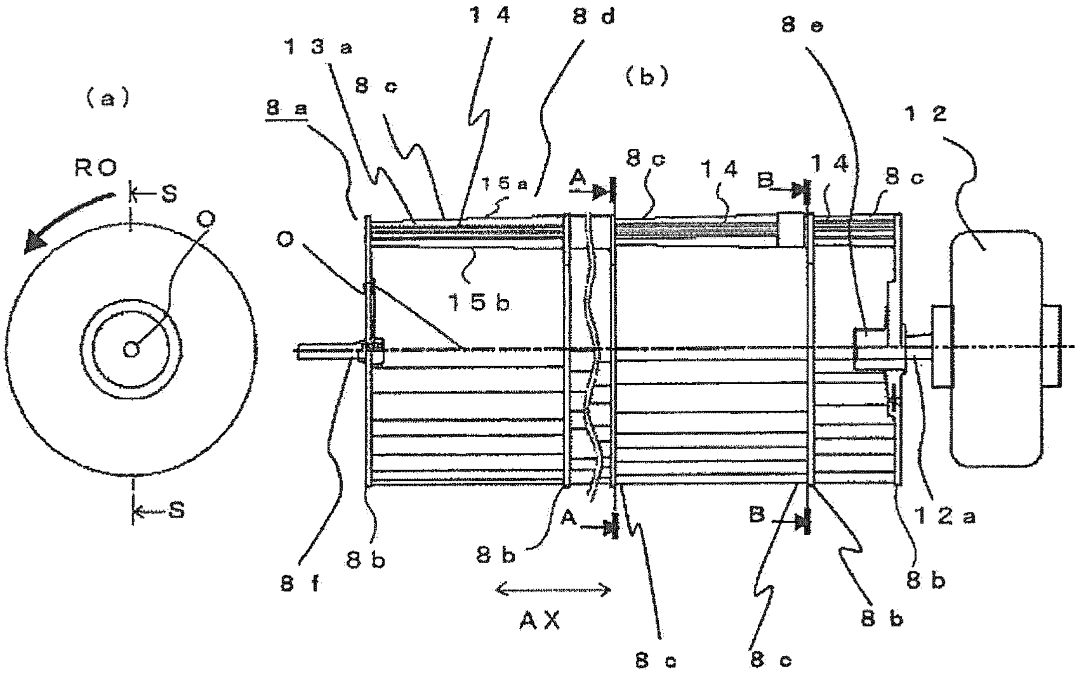


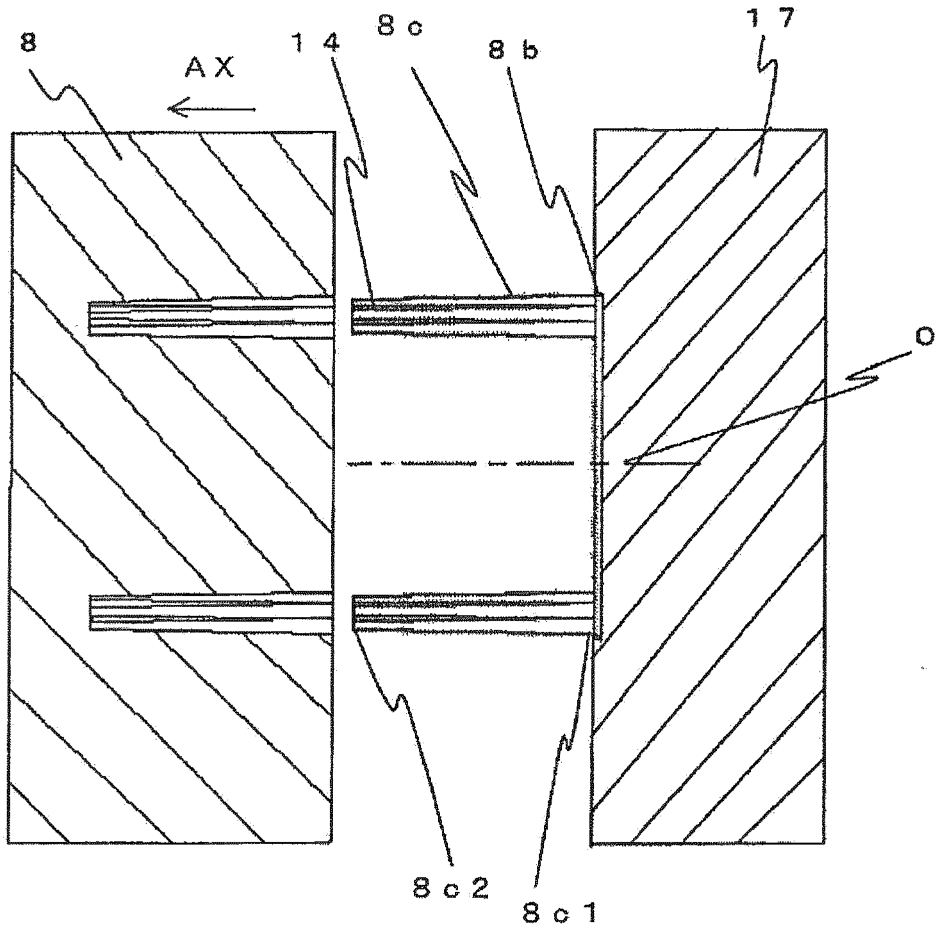
FIG. 11



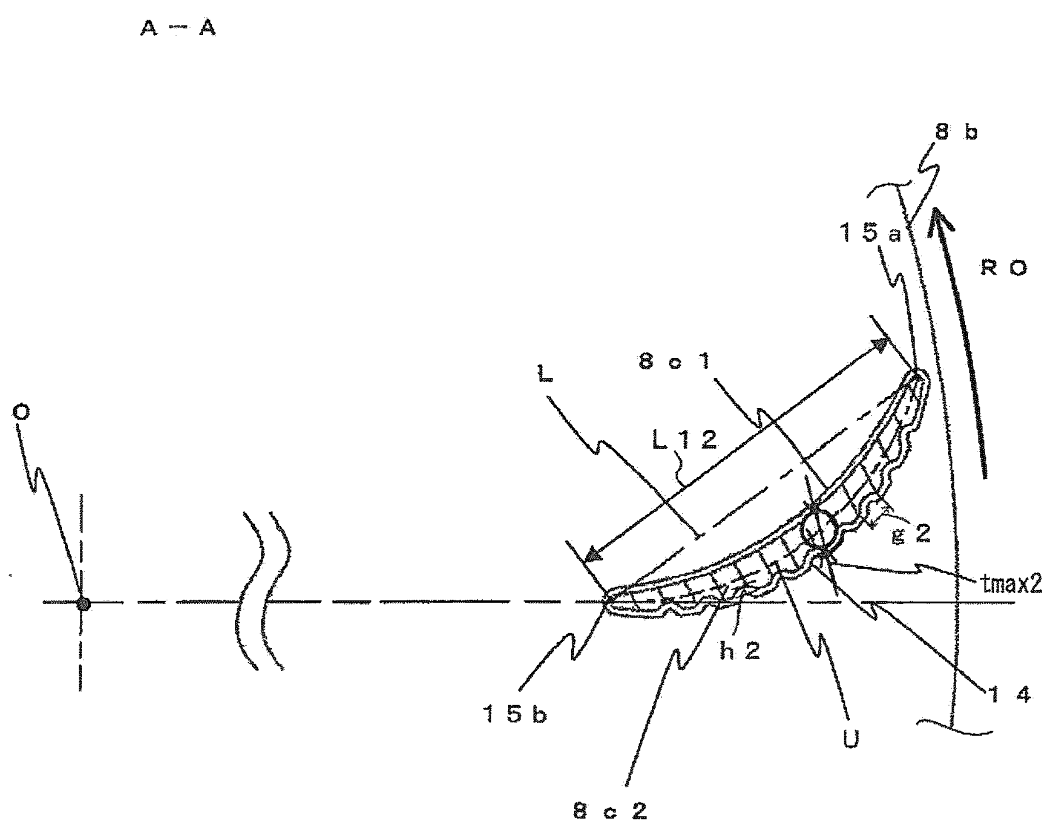
F I G. 1 2


(a)
RO
S
O
S
(b)
14
8d
8e
13a
8c
8a
12
8c
14
14
8c
15a
A
B
O
15b
A
B
8f
8b
8b
AX
12a
8b
8b
8c
8c

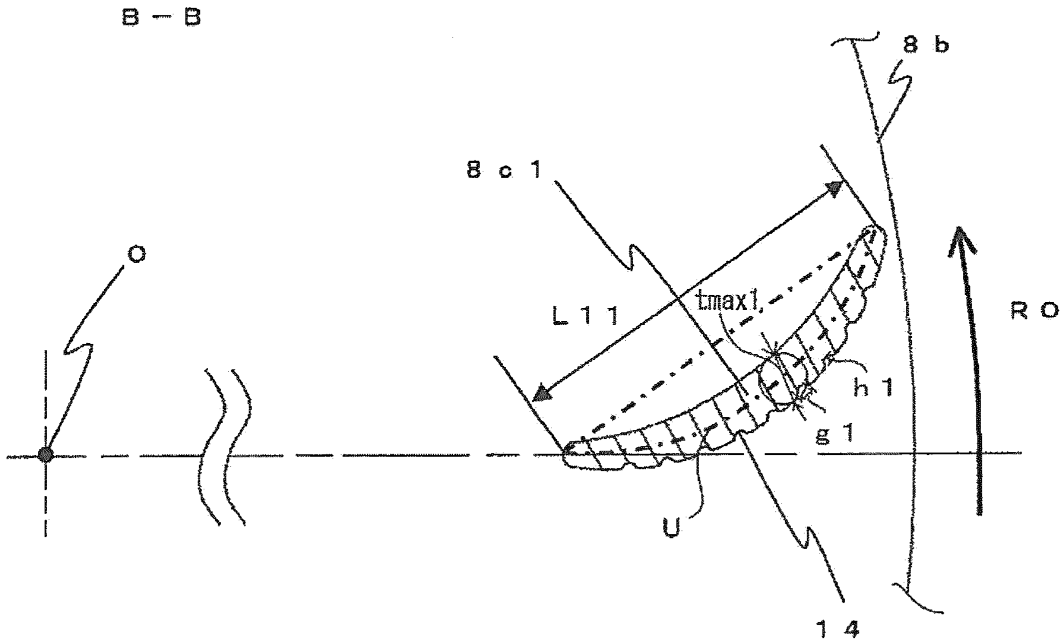
F I G. 1 3



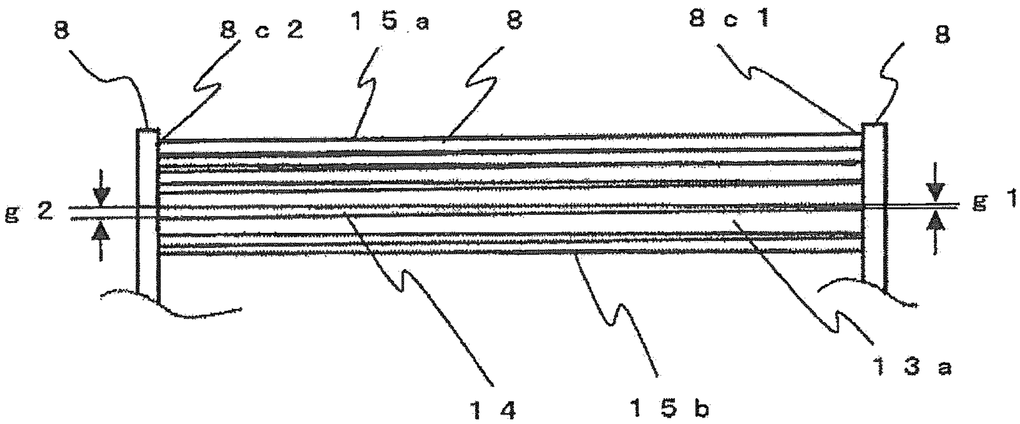
F I G. 1 4



ＦＩＧ．１５



ＦＩＧ．１６



F I G. 1 7

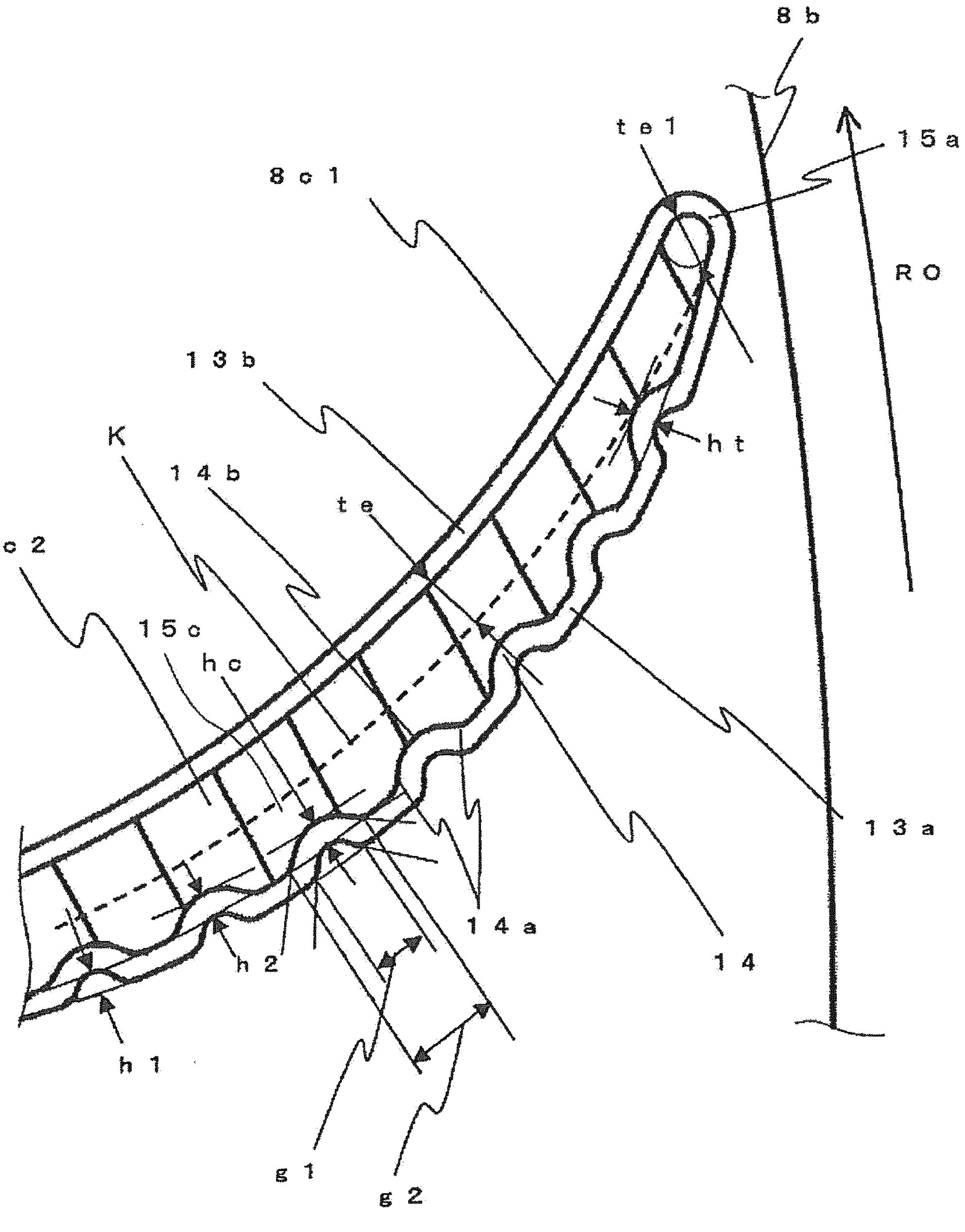


FIG. 18

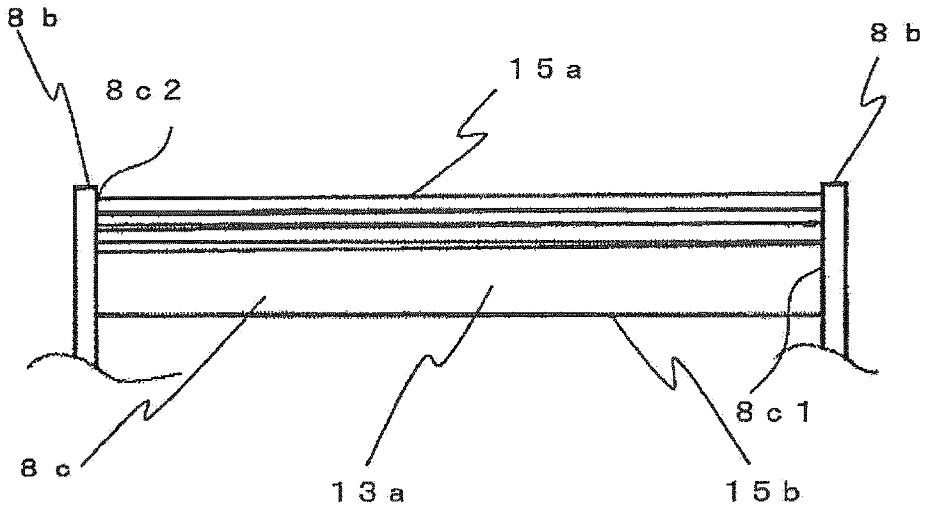
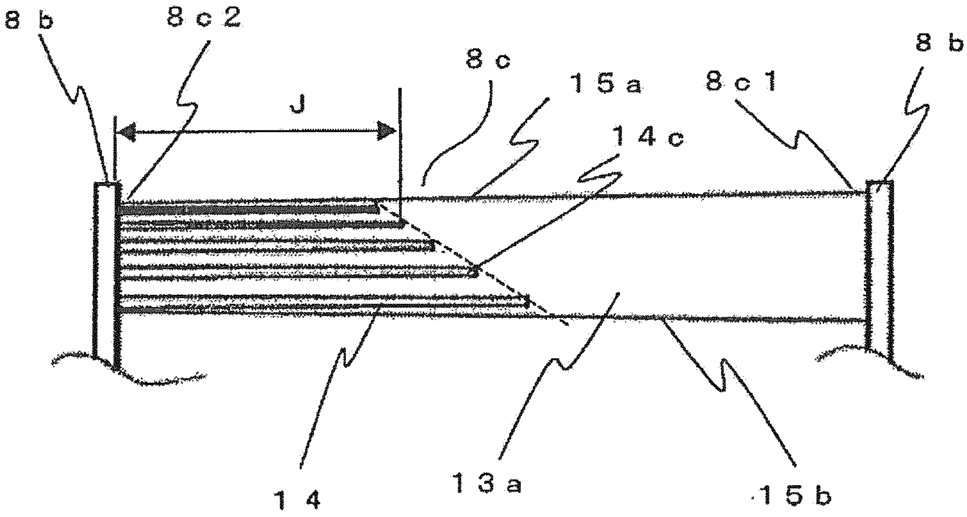
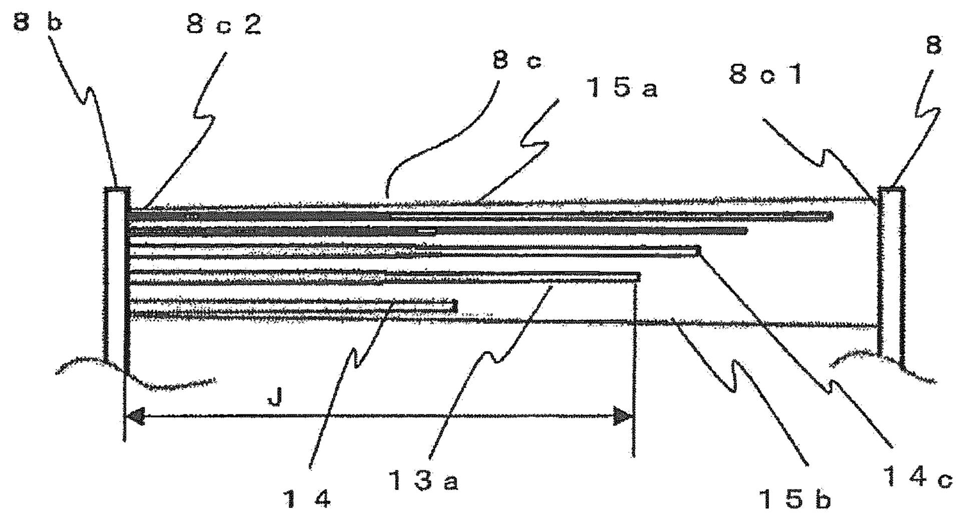


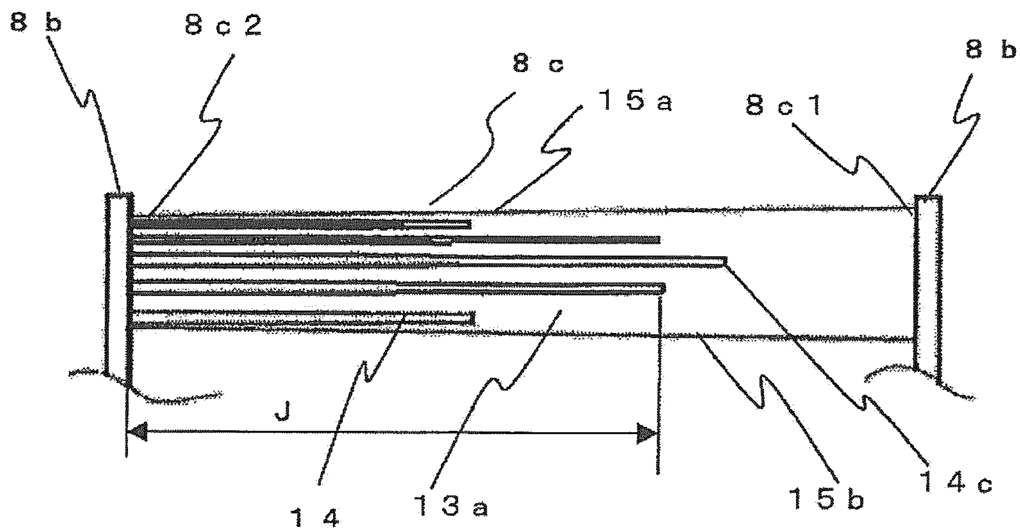
FIG. 19



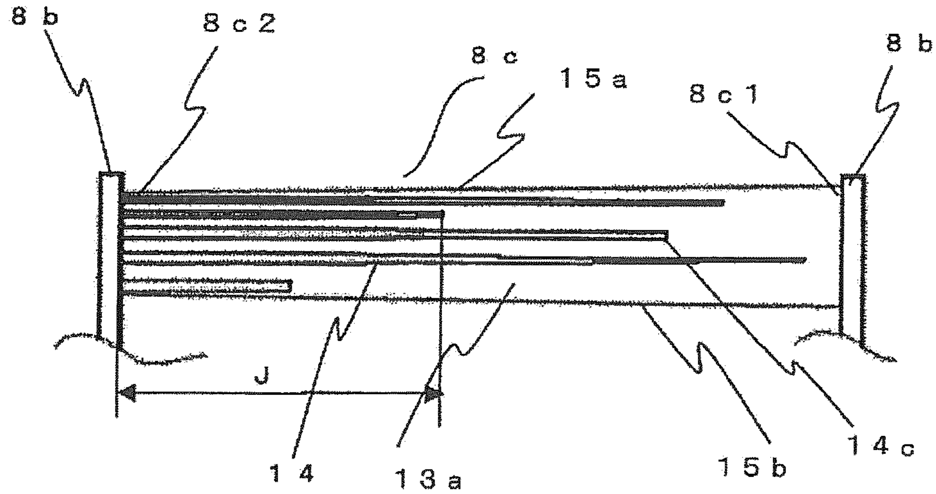
ＦＩＧ．２０



F I G. 2 1



F I G. 2 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/001945

A. CLASSIFICATION OF SUBJECT MATTER
F04D17/04(2006.01)i, *F04D29/26*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04D17/04, F04D29/26

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2007-10259 A (Hitachi Appliances, Inc.), 18 January 2007 (18.01.2007), paragraphs [0039] to [0041]; fig. 10 to 11, 16 to 17 (Family: none)	1,6-10 11-15
X Y	JP 9-280196 A (Daikin Industries, Ltd.), 28 October 1997 (28.10.1997), paragraphs [0030] to [0031]; fig. 15 to 16 (Family: none)	1,6-10 11-15

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "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
01 June, 2010 (01.06.10)	15 June, 2010 (15.06.10)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/001945

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 49007/1988(Laid-open No. 152096/1989) (Matsushita Electric Industrial Co., Ltd.), 19 October 1989 (19.10.1989), specification, page 2, line 11 to page 3, line 4; fig. 4 to 5 (Family: none)	11-15
Y	JP 2009-293616 A (Daikin Industries, Ltd.), 17 December 2009 (17.12.2009), paragraph [0017] & WO 2009/136584 A1	12-15

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/001945

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The matter common to the inventions in claims 1 - 15 pertains to a flowing-through fan equipped with "a plurality of concaved grooves which are provided on the negative pressure surface of a blade as a rear surface with respect to the rotational direction of the blade and extend in the afore-said directional direction".

(continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1, 6 - 15

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/001945

Continuation of Box No.III of continuation of first sheet(2)

However, the search revealed that the above-said flowing-through fan is disclosed in JP 2007-10259 A (Hitachi Appliances, Inc.), 18 January 2007 (18.01.2007), paragraphs 39 - 41, fig. 10 - 11, 16 - 17, and JP 9-280196 A (Daikin Industries, Ltd.), 28 October 1997 (28.10.1997), paragraphs 30 - 31, fig. 15 - 16, and therefore, the common matter is not a special technical feature.

Furthermore, since any other matter considered to be a common special technical feature cannot be found, the inventions in claims 1, 6 - 15, claims 2, 5, claims 3, 4 cannot recognized to satisfy unity of invention.

Form PCT/ISA/210 (extra sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 3210093 A **[0003]**