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

(11) EP 3 085 966 A1

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

(43) Date of publication:
26.10.2016 Bulletin 2016/43

(21) Application number: **13899760.6**

(22) Date of filing: **20.12.2013**

(51) Int Cl.:
F04D 29/32 *(2006.01)*

(86) International application number:
PCT/JP2013/084322

(87) International publication number:
WO 2015/092924 (25.06.2015 Gazette 2015/25)

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

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

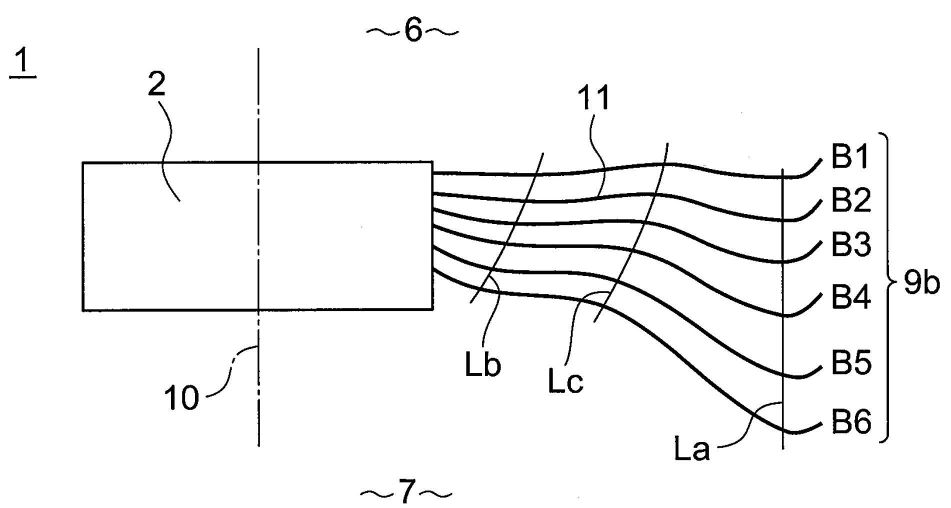
(72) Inventors:
- **KATO, Yasuaki**
  Tokyo 100-8310 (JP)
- **TADOKORO, Takahide**
  Tokyo 100-8310 (JP)
- **KONO, Atsushi**
  Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) **AXIAL FLOW FAN**

(57) Provided is an axial flow blower (100), including: a propeller fan (1); and a motor (4) configured to rotate the propeller fan (1). The propeller fan (1) includes: a hub (2); and a plurality of blades (3) supported by the hub (2). A pressure surface (9b) of each of the plurality of blades includes a protruding portion (11) curved so as to swell to a suction side (6). A height of the protruding portion (11) of each of the plurality of blades on a trailing edge side is larger than a height of the protruding portion (11) on a leading edge side. A radial position of an apex (11c) of the protruding portion (11) on the trailing edge side is located on a radially inner side with respect to a radial position of the apex (11c) of the protruding portion (11) on the leading edge side.

FIG. 4



EP 3 085 966 A1

Description

Technical Field

[0001] The present invention relates to an axial flow blower.

Background Art

[0002] As an axial flow blower achieving reduction in noise through improvement of a blade structure, an axial flow blower disclosed in Patent Literature 1 is exemplified. In the axial flow blower, a radial center portion of a trailing edge of each blade is formed into a protruding shape curved so as to swell to a suction side, thereby equalizing a blowing-out velocity of the air in a radial direction of the blade.

Citation List

Patent Literature

[0003] [PTL 1] JP 4501575 B2 (mainly FIG. 3 and FIG. 8)

Summary of Invention

Technical Problem

[0004] However, in the above-mentioned related-art axial flow blower, when the air is abruptly moved in the radial direction, turbulence of an air stream is generated, which may lead to increase in noise.

[0005] The present invention has been made in view of the above, and has an object to provide an axial flow blower capable of preventing increase in noise.

Solution to Problem

[0006] In order to achieve the above-mentioned object, according to one embodiment of the present invention, there is provided an axial flow blower, including: a propeller fan; and a driving unit configured to rotate the propeller fan, the propeller fan including: the hub; and a plurality of blades supported by the hub, in which a pressure surface of each of the blades includes a protruding portion curved so as to swell to a suction side, in which a height of the protruding portion of the each of the blades on a trailing edge side is larger than a height of the protruding portion on a leading edge side, and in which a radial position of an apex of the protruding portion on the trailing edge side is located on a radially inner side with respect to a radial position of the apex of the protruding portion on the leading edge side.

[0007] Further, an outer peripheral edge of the each of the blades may be curved so as to bend to the suction side.

[0008] Further, a position of an inner end of the protruding portion on the trailing edge side may be located on the radially inner side with respect to a position of the inner end of the protruding portion on the leading edge side.

[0009] Still further, a width dimension of the protruding portion on the trailing edge side may be larger than a width dimension of the protruding portion on the leading edge side.

Advantageous Effects of Invention

[0010] According to the one embodiment of the present invention, the increase in noise can be prevented.

Brief Description of Drawings

[0011]

FIG. 1 is a sectional view of an axial flow blower according to a first embodiment of the present invention.
FIG. 2 is a perspective view of a propeller fan of the axial flow blower according to the first embodiment.
FIG. 3 is a plan view for illustrating one of blades according to the first embodiment as a representative example.
FIG. 4 is a view for illustrating the propeller fan according to the first embodiment when circumferential changes of a pressure surface are projected on a radial plane including a rotation axis.
FIG. 5 is a view for particularly illustrating only the pressure surface in one radial cross-section in the same manner as that of FIG. 4.

Description of Embodiment

[0012] Now, an axial flow blower according to an embodiment of the present invention is described with reference to the accompanying drawings. Note that, in the drawings, the same reference symbols represent the same or corresponding parts.

First Embodiment

[0013] FIG. 1 is a sectional view of an axial flow blower according to a first embodiment of the present invention, and FIG. 2 is a perspective view of a propeller fan of the axial flow blower according to the first embodiment. An axial flow blower 100 includes a propeller fan 1, a motor 4 being a driving unit, and a bellmouth 5.

[0014] The propeller fan 1 includes a hub 2 and a plurality of blades 3. The plurality of blades 3 are supported by the hub 2, and are arranged in a radiate manner on an outer peripheral surface of the hub 2 having substantially a columnar shape (including a truncated conical shape). Note that, in the illustrated example, the propeller fan including three blades is illustrated.

[0015] A center portion of the hub 2 is connected to the motor 4, and the propeller fan 1 is rotated by a driving force of the motor 4. The bellmouth 5 is arranged on a radially outer side of the propeller fan 1. That is, under a state in which a proper gap is defined between an outer peripheral portion of the propeller fan 1 and an inner peripheral portion of the bellmouth 5, the propeller fan 1 is surrounded by the bellmouth 5. Note that, an upper space on the drawing sheet of FIG. 1 corresponds to a suction side 6, and a lower space on the drawing sheet of FIG. 1 corresponds to a blowing-out side 7.

[0016] Each of the blades 3 is a forward blade having a leading edge extending to a forward side in a rotating direction RD. Among edges 8 of each of the blades 3, an edge facing the forward side in the rotating direction RD is referred to as a leading edge 8a, and an edge facing a backward side in the rotating direction RD is referred to as a trailing edge 8c. A portion connecting a radially outer portion of the leading edge 8a and a radially outer portion of the trailing edge 8c to each other is referred to as an outer peripheral edge 8b. Further, a portion connecting each of the blades 3 and the hub 2 to each other is referred to as a connection edge 8d.

[0017] One surface of each blade 3 surrounded by the leading edge 8a, the outer peripheral edge 8b, the trailing edge 8c, and the connection edge 8d as described above is referred to as a suction surface 9a, and the other surface thereof is referred to as a pressure surface 9b. The suction surface 9a is a surface on the suction side 6, and the pressure surface 9b is a surface on the blowing-out side 7. Further, a rotation center line of the propeller fan 1 is referred to as a rotation axis 10. The rotating direction RD of the propeller fan is schematically indicated by the outline arrows of the drawings, and flows of the air are schematically indicated by the dashed arrows.

[0018] FIG. 3 is a plan view for illustrating one of the blades as an representative example, and FIG. 4 is a view for illustrating the propeller fan according to the first embodiment when circumferential changes of the pressure surface are projected on a radial plane including the rotation axis. In addition, FIG. 5 is a view for particularly illustrating only the pressure surface in one radial cross-section in the same manner as that of FIG. 4. The dot-and-dash lines A1 to A6 of FIG. 3 correspond to lines along which radial cross-sections of the hub and the blade are taken. The dot-and-dash lines A1 to A6 include the rotation axis, and extend continuously from the connection edge to the outer peripheral edge. Further, the lines B1 to B6 of FIG. 4 respectively correspond to the cross-sections of the pressure surface taken along the dot-and-dash lines A1 to A6. In addition, FIG. 5 is an illustration of only the pressure surface taken along the line B3 of FIG. 4.

[0019] A shape of the pressure surface of each of the blades 3 is described while one pressure surface illustrated in FIG. 5 is taken as an example. The pressure surface 9b includes a protruding portion 11 curved so as to swell to the suction side 6. Assuming that a straight line BL (chain double-dashed line of FIG. 5) is brought into abutment on the pressure surface 9b from the blowing-out side 7, a portion swelling from the straight line BL to the suction side 6 corresponds to the protruding portion 11.

[0020] An end portion of the protruding portion 11 on the outer peripheral edge side of each blade 3 is referred to as an outer end 11a of the protruding portion, and an end portion of the protruding portion 11 on the connection edge side thereof is referred to as an inner end 11b. A most distant point of the protruding portion 11 from the straight line BL (chain double-dashed line) is referred to as an apex 11c of the protruding portion. A distance between the apex 11c of the protruding portion 11 and the straight line BL (chain double-dashed line) is referred to as a height H of the protruding portion 11. A radial distance (denoted by W in FIG. 5) between the outer end 11a and the inner end 11b of the protruding portion 11 is referred to as a width dimension W of the protruding portion 11. Note that, in FIG. 3 and FIG. 4, a line connecting points of the outer end 11a of the protruding portion 11, a line connecting points of the inner end 11b thereof, and a line connecting points of the apex 11c thereof are indicated by the curved lines La, Lb, and Lc, respectively.

[0021] In radial cross-sections of each of the blades 3 according to the first embodiment, within an angle range where the radial cross-sections extend continuously from the connection edge 8d to the outer peripheral edge 8b (angle range defined between the dot-and-dash lines A1 and A6 of FIG. 3), the pressure surface 9b includes the protruding portion 11 curved so as to swell to the suction side 6. The outer end 11a of the protruding portion 11 is positioned on a radially inner side with respect to the outer peripheral edge 8b of each of the blades 3. Further, the height H of the protruding portion 11 on the trailing edge side is larger than the height H of the protruding portion 11 on the leading edge side. As an example, within the angle range defined between the dot-and-dash lines A1 and A6, the height H of the protruding portion 11 becomes larger as approaching to the trailing edge. Further, a radius position (radial position) of the apex 11c of the protruding portion 11 on the trailing edge side is located on the radially inner side with respect to a radius position (radial position) of the apex 11c of the protruding portion 11 on the leading edge side. As an example, within the angle range defined between the dot-and-dash lines A1 and A6, the radial position of the protruding portion 11 is shifted radially inward as approaching to the trailing edge.

[0022] Further, a position of the inner end 11b of the protruding portion 11 on the trailing edge side is located on the radially inner side with respect to a position of the inner end 11b of the protruding portion 11 on the leading edge side. As an example, within the angle range defined between the dot-and-dash lines A1 and A6, the position of the inner end 11b of the protruding portion 11 is shifted radially inward as approaching to the trailing edge. In other words, within the angle range defined between the dot-and-dash lines A1 and A6, a point on the curved line Lb, which is obtained by connecting the points of the inner end 11b of the protruding portion 11, is shifted radially inward as approaching to the trailing edge.

[0023] Further, the width dimension W of the protruding portion 11 on the trailing edge side is larger than the width dimension W of the protruding portion 11 on the leading edge side. As an example, within the angle range defined between the dot-and-dash lines A1 and A6, the width dimension W of the protruding portion 11 becomes larger as approaching to the trailing edge.

[0024] In addition, the outer peripheral edge 8b of each of the blades 3 is curved so as to bend to the suction side 6.

[0025] Next, operation of the axial flow blower having the above-mentioned configuration is described. The hub 2 connected to the motor 4, and also the blades 3 are rotated by the driving force of the motor 4 as indicated by the reference symbol RD.

[0026] Owing to this rotation, the pressure surface 9b of each blade 3 pushes the air in the rotational region of the blade 3 to the blowing-out side 7, with the result that pressure is reduced on the suction surface 9a side of the blade 3 by movement of the suction surface 9a. Thus, the air is caused to flow from the suction side 6 into the rotational region of the blade 3. Owing to this action of the blade 3, as indicated by the dashed arrows, the air is caused to flow from the suction side 6 to the blowing-out side 7.

[0027] In a general radial distribution of an axial flow velocity at a vicinity of the trailing edge on the blowing-out side of the axial flowblower, the flow velocity increases from the radially inner side toward the radially outer side, and becomes maximum in a region positioned slightly radially outward of a radial center. The flow velocity decreases from the region toward the outer peripheral edge being a position of a maximum radius. Further, on the hub side of each blade, a flow is directed radially outward due to a centrifugal force, thereby reducing a flow rate on the hub side. Accordingly, insufficient flow rate causes the flow to be separated from a blade surface. Due to turbulence generated by the separation, noise may be increased, and efficiency may be reduced due to the separation. Further, on an outer peripheral side with respect to the radial center of the blade, the flow rate is concentrated, thereby increasing the flow velocity. Aerodynamic noise of the propeller fan increases mainly in proportion to the sixth power of the flow velocity. Accordingly, there is a problem in that noise is increased along with increase in flow velocity. As described above, on the blowing-out side, the distribution of the flow velocity appears in the radial direction of the blade. Further, the air flows slower on the hub side, whereas the air flows faster on the outer peripheral edge side. As a result, there arise a problem of increase in noise and a problem of reduction in efficiency, which are caused by the distribution of the flow velocity.

[0028] In contrast, in the first embodiment, the pressure surface 9b of each of the blades 3 includes the protruding portion 11, thereby suppressing appearance of the distribution of the flow rate in the radial direction, which causes the above-mentioned problems. The pressure surface 9b acts so as to push out the air in a direction of the blowing-out side 7. The protruding portion 11 functions as an escape route for the pushed air, and the flow directed toward the protruding portion 11 is generated on the pressure surface 9b. The radial position of the apex 11c of the protruding portion 11 on the trailing edge side is located on the radially inner side with respect to the radial position of the apex 11c of the protruding portion 11 on the leading edge side. Accordingly, it is possible to obtain such an effect that the air on the radially outer side of the pressure surface 9b is moved to the radially inner side. Thus, it is possible to reduce movement of the air to the radially outer side caused by the centrifugal force. Further, the height H of the protruding portion 11 on the trailing edge side is larger than the height H of the protruding portion 11 on the leading edge side. Accordingly, the effect of moving the air to the radially inner side can be further enhanced, and imbalanced concentration of the flow rate on the radially outer side can be further suppressed. Thus, the distribution of the flow rate in the radial direction can be almost equalized.

[0029] Further, in the radial cross-sections, the protruding portion 11 is formed over the entire angle range where the radial cross-sections extend continuously from the connection edge 8d to the outer peripheral edge 8b (entire angle range where the pressure surface extends continuously in the radial direction from the connection edge 8d to the outer peripheral edge 8b). Accordingly, without abruptly changing the flow of the air, the distribution of the flow rate in the radial direction can be controlled. Thus, turbulence of the air can be suppressed, and increase in noise and reduction in efficiency caused by the turbulence of the air can be prevented.

[0030] Further, in the propeller fan, at a vicinity of the outer peripheral edge, a swirling flow is generated from the pressure surface to the suction surface through the outer side of the outer peripheral edge due to a pressure difference between the pressure surface and the suction surface. Regarding this, in the first embodiment, it seems that the radially outer side of the protruding portion is inclined so as to push the air to the inner peripheral side, thereby increasing the pressure and intensifying the swirling flow from the pressure surface to the suction surface. However, the outer end of the protruding portion is arranged on the inner peripheral side with respect to the outer peripheral edge, thereby preventing intensification of the swirling flow generated on the outer side of the outer peripheral edge.

[0031] Further, in the first embodiment, the outer peripheral edge of each of the blades is curved so as to bend to the suction side. That is, the outer peripheral edge 8b is positioned on the suction side 6 with respect to the straight line BL (chain double-dashed line) of FIG.

5. Accordingly, even in the above-mentioned case where the swirling flow from the pressure surface to the suction surface may be generated, because the outer peripheral edge is curved to bend to the suction side, a pressure change is started before the air is caused to flow out from the pressure surface to the outer side of the outer peripheral edge. Consequently, the abrupt pressure change can be prevented from occurring afterward, and turbulence caused by the swirling can be reduced. Further, even if the swirling flow is generated, a position of the swirling flow can be shifted from the suction surface to the suction side. Thus, an influence of the swirling flow can be lessened.

[0032] Further, in the first embodiment, the position of the inner end 11b of the protruding portion 11 on the trailing edge side is located on the radially inner side with respect to the position of the inner end 11b of the protruding portion 11 on the leading edge side. Accordingly, as compared to a mode of merely forming the protruding portion, it is possible to intensify an effect of increasing the radially-inner-side flow rate of the air passing through the propeller fan.

[0033] Still further, in the first embodiment, the width dimension W of the protruding portion 11 on the trailing edge side is larger than the width dimension W of the protruding portion 11 on the leading edge side. Accordingly, with a view to equalizing the radial distribution of the flow velocity on the blowing-out side by forming the protruding portion, it is possible to enlarge a controllable range of the radial distribution of the flow velocity on the blowing-out side.

[0034] As described above, in the axial flow blower according to the first embodiment, the distribution of the axial flow velocity on the blowing-out side can be almost equalized. Accordingly, increase in noise and reduction in efficiency, which are caused by the extensive distribution of the flow velocity, can be prevented, thereby being capable of obtaining the propeller fan capable of achieving reduction in noise and high efficiency. In addition, it is possible to suppress turbulence of the flow, which may be generated in order to almost equalize the flow velocity. Thus, effects of reducing noise and increasing efficiency can be enhanced.

[0035] Although the details of the present invention are specifically described above with reference to the preferred embodiment, it is apparent that persons skilled in the art may adopt various modifications based on the basic technical concepts and teachings of the present invention.

[0036] As an application example of the present invention, an outdoor unit of an air-conditioning apparatus is given. When the axial flow blower according to the present invention is applied to a blower of the outdoor unit of the air-conditioning apparatus, it is possible to reduce aerodynamic noise caused when generating a desired quantity of air, and to reduce necessary power. In other words, it is possible to obtain the air-conditioning apparatus capable of reducing noise and excellent in energy saving performance.

Reference Signs List

[0037] 1 propeller fan, 2 hub, 3 blade, 4 motor, 5 bellmouth, 6 suction side, 7 blowing-out side, 8a leading edge, 8b outer peripheral edge, 8c trailing edge, 8d connection edge, 9a suction surface, 9b pressure surface, 10 rotation axis, 11 protruding portion, 11a outer end of protruding portion, 11b inner end of protruding portion, 11c apex of protruding portion, 100 axial flow blower

Claims

1. An axial flow blower, comprising:

a propeller fan; and
a driving unit configured to rotate the propeller fan,
the propeller fan comprising:

the hub; and
a plurality of blades supported by the hub,

wherein a pressure surface of each of the blades comprises a protruding portion curved so as to swell to a suction side,
wherein a height of the protruding portion of the each of the blades on a trailing edge side is larger than a height of the protruding portion on a leading edge side, and
wherein a radial position of an apex of the protruding portion on the trailing edge side is located on a radially inner side with respect to a radial position of the apex of the protruding portion on the leading edge side.

2. An axial flow blower according to claim 1, wherein an outer peripheral edge of the each of the blades is curved so as to bend to the suction side.

3. An axial flow blower according to claim 1 or 2, wherein a position of an inner end of the protruding portion on the trailing edge side is located on the radially inner side with respect to a position of the inner end of the protruding portion on the leading edge side.

4. An axial flow blower according to any one of claims 1 to 3, wherein a width dimension of the protruding portion on the trailing edge side is larger than a width dimension of the protruding portion on the leading edge side.

FIG. 1

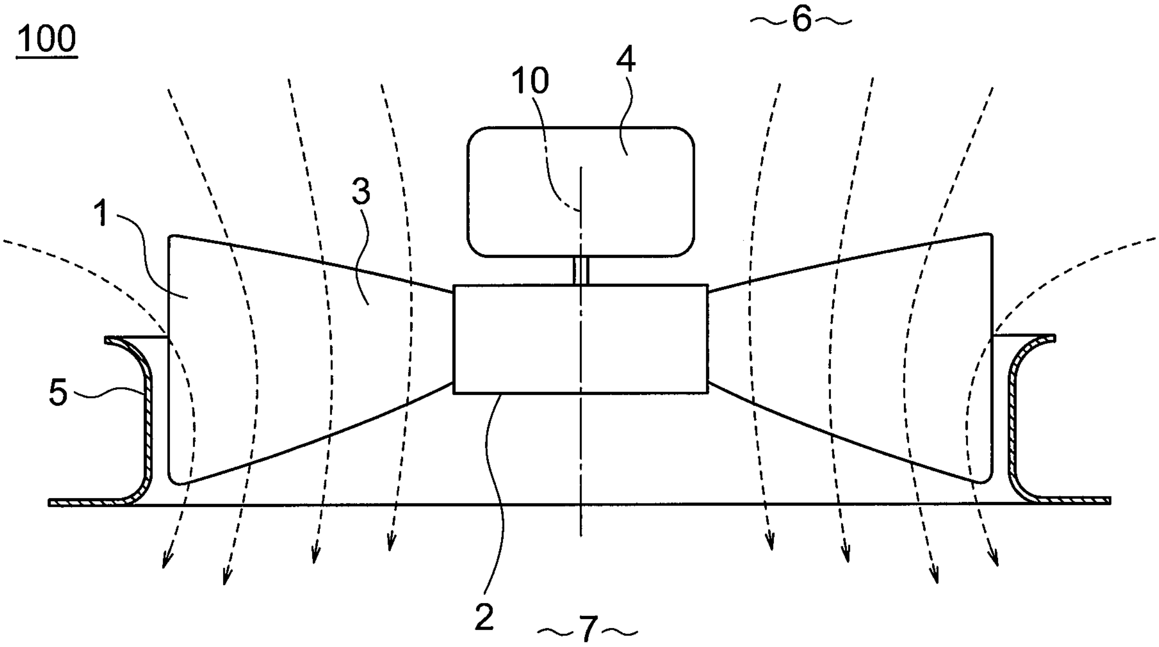


FIG. 2

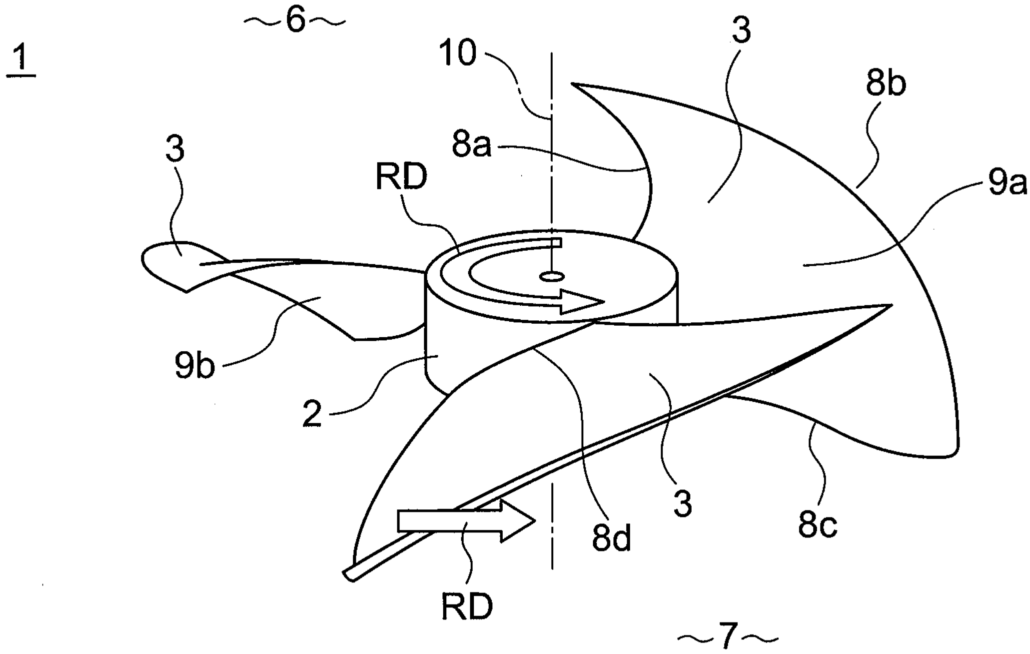


FIG. 3

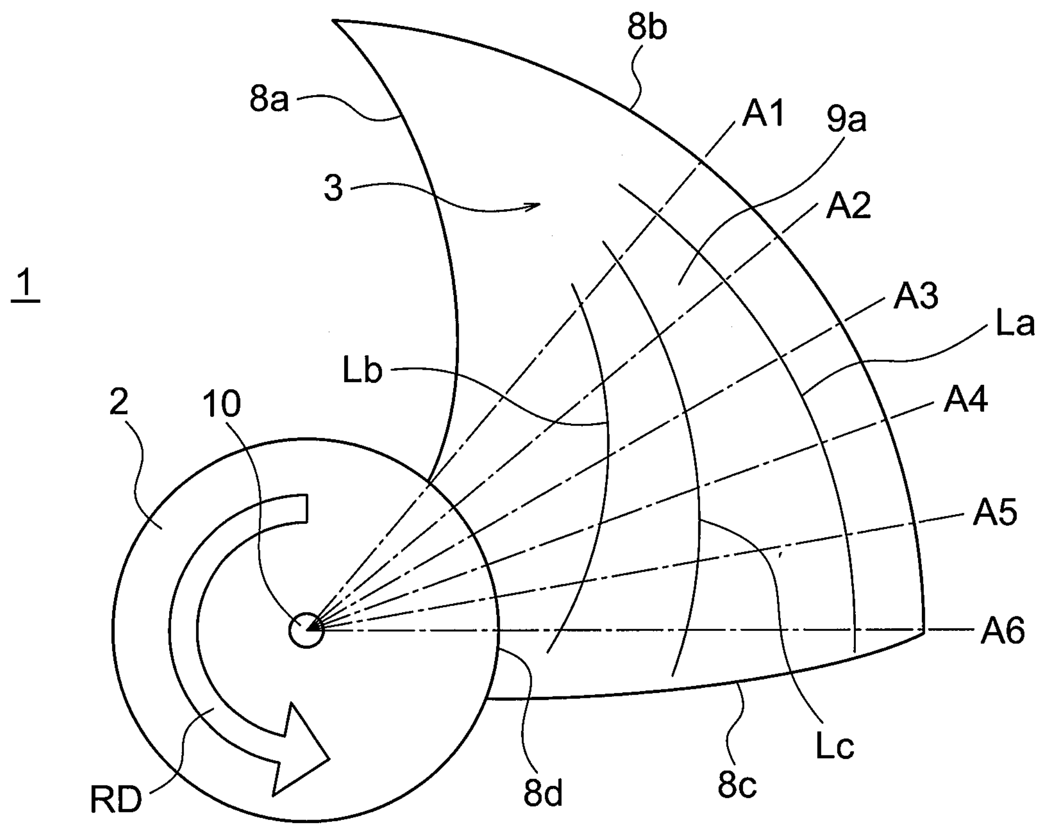

8b
8a
A1
9a
3
A2
1
A3
La
Lb
A4
2
10
A5
A6
RD
8d
8c
Lc

FIG. 4

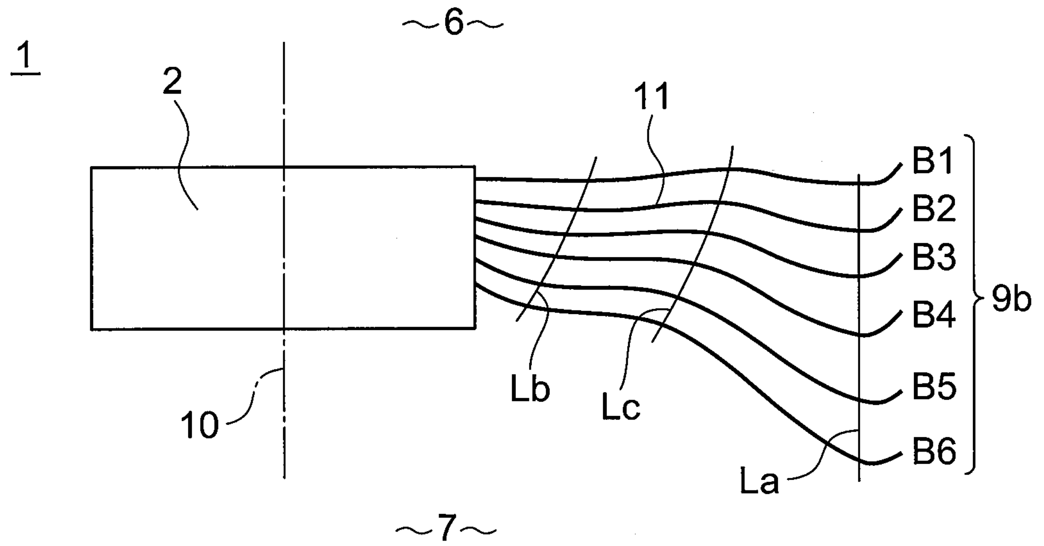
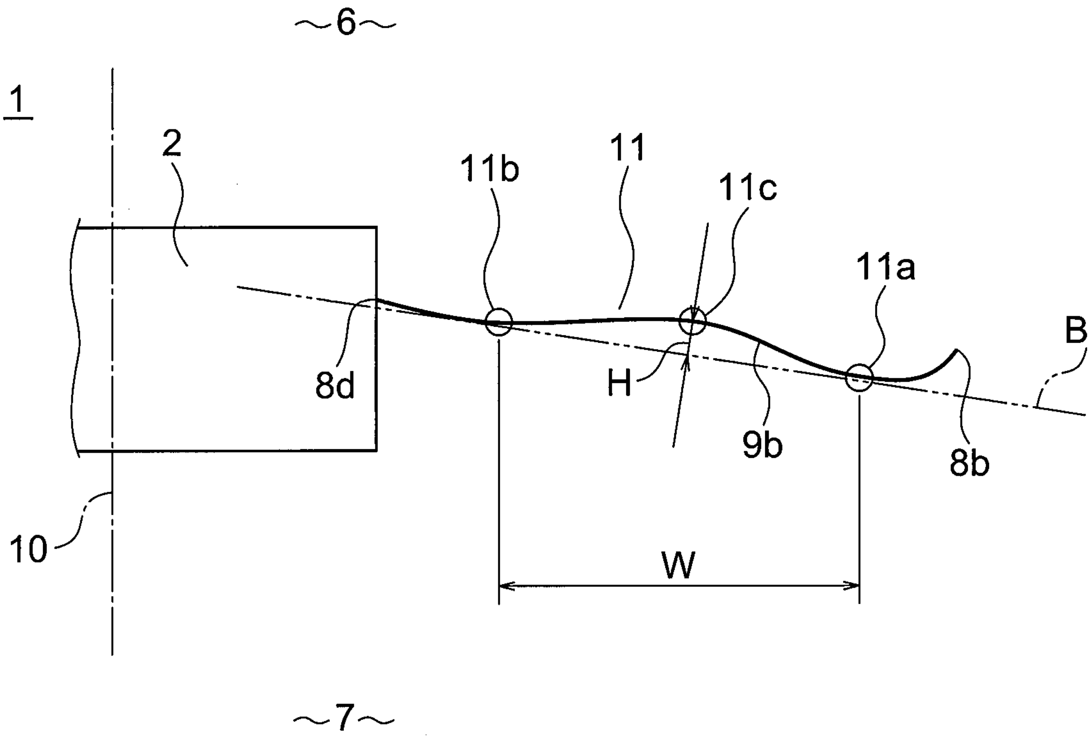

6
1
2
11
B1
B2
B3
B4
9b
B5
B6
10
Lb
Lc
La
7

FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/084322

A. CLASSIFICATION OF SUBJECT MATTER
F04D29/32(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04D29/32

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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 2006-37800 A (Mitsubishi Electric Corp.), 09 February 2006 (09.02.2006), paragraph [0025]; all drawings & US 2008/0019826 A1 & EP 1783376 A1 & WO 2006/011333 A1	1,3-4 2-4
Y	JP 2013-213420 A (Panasonic Corp.), 17 October 2013 (17.10.2013), all drawings (Family: none)	2-4
Y	JP 2001-90693 A (Matsushita Electric Industrial Co., Ltd.), 03 April 2001 (03.04.2001), all drawings & EP 1087146 A2	2-4

☒ 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
05 February, 2014 (05.02.14)	18 February, 2014 (18.02.14)

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/JP2013/084322

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2013-249787 A (Daikin Industries, Ltd.), 12 December 2013 (12.12.2013), fig. 1 to 3 (Family: none)	2-4

Form PCT/ISA/210 (continuation of second 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 4501575 B **[0003]**