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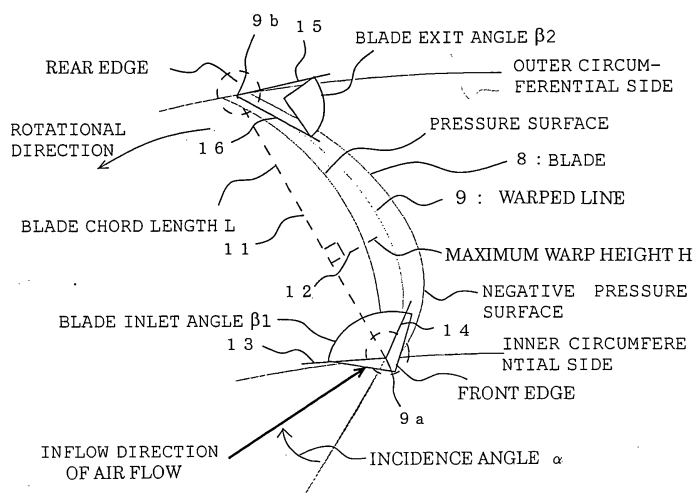
(54) **SIROCCO FAN AND AIR CONDITIONER**

(57) To provide a sirocco fan capable of reducing a noise value and a number of revolutions when obtaining a predetermined air-blowing amount and an air-conditioning apparatus provided with the sirocco fan.

In the sirocco fan, when a fan diameter is defined as D, a maximum warp height is defined as H, a blade chord

length is defined as L, a radius of a front edge at an inner circumferential side of the blade is defined as R, a blade inlet angle is defined as β_1 , and a blade exit angle is defined as β_2 , the following formulas are satisfied, $0.18 \leq H/L \leq 0.26$, $R/L \leq 0.11$, $100^\circ \leq \beta_1 \leq 130^\circ$, and $26^\circ \leq \beta_2 \leq 32^\circ$.

FIG. 2



Description

Technical Field

5 **[0001]** The present invention relates to a sirocco fan in which a noise is reduced and an air-blowing characteristic is improved, and to an air-conditioning apparatus provided with the same.

Background Art

10 **[0002]** Hitherto, in air-conditioning apparatuses, air purification systems, and so forth, sirocco fans are often used. The sirocco fan is composed of a whorl-shaped scroll and a large number of proclinated blades rotatably disposed in the scroll and arranged in a cylindrical manner. As the air-conditioning apparatus provided with such a sirocco fan, for example, the sirocco fan of a window-type air conditioner that is disclosed in a patent document 1 exists. That is, in the sirocco fan of the window-type air conditioner, which is formed by including a shroud and a large number of blades
15 disposed on the shroud at constant intervals, the blade is formed to have a blade exit angle of from 125 to 137 degrees, a blade inlet angle of from 58 to 63 degrees, a solidity (L_1/L_2) of from 0.75 to 0.85, an inner/outer diameter ratio (d_1/d_2) of from 0.82 to 0.86, and a maximum warp position of from 0.3 to 0.4. By forming the blade to have a configuration as described above, it is specified that a noise of the sirocco fan is not increased even when a rotation speed is increased with an air-blowing amount being preserved.

20 **[0003]** [Patent Document 1] Japanese Unexamined Patent Application Publication No. 2001-323895 (Claim 1, Fig. 1 through Fig. 3)

Disclosure of Invention

25 Problems to be Solved by the Invention

[0004] There were problems such that, since an air-blowing amount of the sirocco fan at a predetermined noise value is small, and a capability of a heat exchanger is lowered in the air-conditioning apparatus on which the conventional sirocco fan is mounted, a load of a compressor is increased, and a COP (performance coefficient) being lowered. In
30 addition, if the air-blowing amount of the sirocco fan is increased in order to suppress the lowering of the COP, the noise value is increased to give an uncomfortable feeling to users.

[0005] In light of the above-described problems, an object of the present invention is to provide a sirocco fan capable of obtaining a large air-blowing amount at a time of a predetermined noise occurrence, in other words, capable of reducing a noise value and a number of revolutions when obtaining a predetermined air-blowing amount, and an air-conditioning
35 apparatus provided with the same.

Means for Solving the Problems

40 **[0006]** A sirocco fan of the present invention is configured such that, in the sirocco fan provided with a scroll and a large number of blades rotatably disposed in the scroll and arranged in a cylindrical manner, when a fan diameter is defined as D , a maximum warp height is defined as H , a blade chord length is defined as L , a radius of a front edge of an inner circumferential side of the blade is defined as R , a blade inlet angle is defined as β_1 , and a blade exit angle is defined as β_2 , the following formulas are specified: $0.18 \leq H/L \leq 0.26$, $R/L \leq 0.11$, $100^\circ \leq \beta_1 \leq 130^\circ$, $26^\circ \leq \beta_2 \leq 32^\circ$.

45 Advantages

[0007] According to the present invention, regarding a blade shape of a sirocco fan, when a fan diameter is defined as D , a maximum camber height is defined as H , a blade chord length is defined as L , a radius of a front edge of an inner circumferential side of the blade is defined as R , a blade inlet angle is defined as β_1 , and a blade exit angle is defined as β_2 , by making $0.18 \leq H/L \leq 0.26$, $R/L \leq 0.11$, $100^\circ \leq \beta_1 \leq 130^\circ$, and $26^\circ \leq \beta_2 \leq 32^\circ$, an air-blowing amount at the time of a predetermined noise occurrence can be increased and in the case of an air-conditioning apparatus, the COP can be improved.

Brief Description of Drawings

55 **[0008]**

[Fig. 1] Fig. 1 is a schematic plan view (a) and side elevation (b) illustrating an inner construction of an indoor unit

of an air-conditioning apparatus provided with a sirocco fan in a first embodiment of the present invention.

[Fig. 2] Fig. 2 is an explanatory view of parameters indicating a blade shape of the sirocco fan in the first embodiment.

[Fig. 3] Fig. 3 is a view illustrating a blade shape of the sirocco fan in the first embodiment.

[Fig. 4] Fig. 4 is a comparative view of the blade shape of the sirocco fan in the first embodiment and that of a conventional blade shape.

[Fig. 5] Fig. 5 is a view illustrating the blade shapes of the sirocco fans in the first and second embodiments.

[Fig. 6] Fig. 6 is a view illustrating a relative velocity distribution of the sirocco fan in the first embodiment.

[Fig. 7] Fig. 7 is a view illustrating a relative velocity distribution of the sirocco fan in the second embodiment.

Reference Numerals

[0009]

- 1 sirocco fan
- 2 fan motor
- 3 heat exchanger
- 4 suction inlet
- 5 blowing-out exit
- 6 scroll
- 7 rotation shaft
- 8 blade
- 9 warped line
- 10 indoor unit
- 11 straight line (blade chord length L)
- 12 perpendicular line
- 13 inner circumferential tangent
- 14 warped line tangent
- 15 outer circumferential tangent
- 16 warped line tangent

Best Modes for Carrying Out the Invention

[0010] Hereinbelow, embodiments of the present invention will be explained with reference to the drawings.

First Embodiment

[0011] Fig. 1 is a schematic plan view (a) and a schematic side elevation (b) illustrating an inner constitution of an indoor unit of an air-conditioning apparatus provided with a sirocco fan of a first embodiment of the present invention.

In Fig. 1, the indoor unit 10 constitutes an indoor air-conditioning apparatus, and is provided with a pair of sirocco fans 1, a fan motor 2 that simultaneously rotationally drives these sirocco fans 1, and a heat exchanger 3 that performs heat-exchanging operation with air that is blown out from the sirocco fans 1. The sirocco fan 1 is provided with a whorl-shaped scroll 6, and a large number of blades that are rotatably disposed in the scroll 6 and arranged in a cylindrical manner. In the drawing, a reference numeral 4 denotes a suction inlet of the air, a reference numeral 5 denotes a blowing outlet for cold air or warm air, and a reference numeral 7 denotes a rotation shaft of the fan motor 2.

[0012] The aforementioned indoor unit 10 is provided with a refrigerating circuit for a refrigerant, which is constituted by a compressor, a condenser, an expansion valve, and an evaporator, all of which being not shown, and is configured so as to perform cooling heating operations in a room, or the like. Further, an example of specifications of the present first embodiment is as follows: the sirocco fan 1 is configured to have a fan-diameter of ϕ 160 mm, a width of 190 mm, the number of the blades of 40, and the heat exchanger 3 is provided with a heat transmission pipe of 12 steps, and an array pitch thereof is 12.7 mm and a step pitch thereof is 20.4 mm, a length in an axial direction of the heat transmission pipe is 700 mm, and a draft resistance ΔP_1 is $23.1 V^{1.3}$ [Pa] (V: velocity[m/s]). Furthermore, the indoor unit 10 is configured to have a depth of 680 mm, a height of 210 mm, and a width of 960 mm.

[0013] The air in the room is sucked in from the suction inlet 4 of the indoor unit 10, and is further sucked in from a suction inlet of the scroll 6 in an axial direction. The air to which a dynamic pressure and a static pressure is applied by a cylindrical blade array that is rotating in the scroll 6 by means of the fan motor 2 is blown out from a blowing outlet that opens to an air trunk in the indoor unit 10 to be heat-exchanged with the heat exchanger 3 installed in the air trunk, then blown out from the blowing outlet 5 into the room while being turned into cool or warm air.

[0014] Fig. 2 is an explanatory view of parameters indicating a blade shape of the sirocco fan. Fig. 3 is a view illustrating

a blade shape of the sirocco fan in the first embodiment. Fig. 4 is a comparative view illustrating a conventional blade shape by superimposing Fig. 3.

[0015] An air-blowing amount of the sirocco fan 1 at a predetermined noise value is decided by relations of parameters D , L , H , β_1 , β_2 , and R of the sirocco fan 1, where a fan-diameter is defined as D , a blade chord length is defined as L , a maximum camber height is defined as H , a radius of a front edge of an inner circumferential side of the blade is defined as R , a blade inlet angle is defined as β_1 , and a blade exit angle is defined as β_2 , respectively. Incidentally, regarding a fan-diameter D and the radius R of the front edge of an inner circumferential side of the blade, illustrations are omitted. Here, definitions of each aforementioned parameters are as follows. The fan-diameter D is a diameter of an outer circumferential circle of the blade 8 of the sirocco fan 1. The blade chord length L is a length of a straight line 11 that connects an inner circumferential end 9a and an outer circumferential end 9b of a warped line 9 of the blade 8. The maximum warp height H is a maximum length of a perpendicular line 12 for the warped line 9 of the blade 8 from the straight line 11. The blade inlet angle β_1 is an angle formed by an inner circumferential tangent 13 and a warped line tangent 14 at the inner circumferential end 9a of the warped line 9 of the blade 8. The blade exit angle β_2 is an angle formed by an outer circumferential tangent 15 and a warped line tangent 16 at the outer circumferential end 9b of the warped line 9 of the blade 8. An incidence angle α is an angle formed by the camber line tangent 14 and an inflow direction of airflow at the inner circumferential end 9a of the warped line 9 of the blade 8. The radius R of the front edge at the inner circumferential side of the blade is a radius of a circular arc portion formed at the front edge of the blade 8.

[0016] On the other hand, when denoting a conventional sirocco fan as a reference numeral 100 denotes, the sirocco fan 100 has a shortcoming such that the air-blowing amount is small at a time of a predetermined noise occurrence compared with that of the sirocco fan 1. This is because the air-blowing amount becomes small at the time of a predetermined noise occurrence because H/L is small, R/L is large, angles of β_1 and β_2 are inappropriate, and so forth. As a result, in a case where the sirocco fan 100 is mounted on the indoor unit 10, performance of the heat exchanger 3 is reduced, loads of the compressor being increased, and the COP being lowered.

[0017] Accordingly, since the air-blowing amount at the time of the predetermined noise occurrence is reduced and performance of the heat exchanger 3 is lowered in a case of the indoor unit on which the sirocco fan 100 is mounted, a temperature difference between a refrigerant temperature and room temperature has to be made large by lowering the refrigerant temperature more than necessary in a cooling operation and raising more than necessary in a heating operation so as to obtain a predetermined air-conditioning capability at the time of the predetermined noise occurrence. Therefore, there is a problem that the load of the compressor is increased and the COP is lowered.

[0018] In Table 1, values of H/L , R/L , β_1 , and β_2 of the sirocco fan 1A of the first embodiment of the present invention and that of the conventional sirocco fan 100 are shown. Incidentally, a L/D value is set to be 0.17.

[0019] [Table 1]

Table 1 Shape Parameter of Blade

	Sirocco Fan 1A	Sirocco Fan 100
H/L	0.22	0.28
R/L	0.16	0.16
β_1	100°	100°
β_2	43°	43°

[0020] In Table 2, a noise value and a number of revolutions are shown at a blown-out airflow amount of 16 m³/min in a case where the sirocco fans 1A and 100 are mounted on the indoor unit 10. All the conditions other than the sirocco fan are the same.

[0021] [Table 2]

Table 2 Noise Value and Number of Revolutions at 16 m³/min

	Sirocco Fan 1A	Sirocco Fan 100
Noise Value (dB)	46.5	47.2
Number of Revolutions (rpm)	1101	1127

[0022] As shown in Tables 1 and 2, by setting $H/L = 0.22$, the noise value and the number of revolutions can be reduced.

[0023] In Table 3, values of H/L , R/L , β_1 , and β_2 of the sirocco fan 1B of the present embodiment of the present invention and that of the conventional sirocco fan 100 are shown.

[0024] [Table 3]

Table 3 Shape Parameters of Blade

	Sirocco Fan 1B	Sirocco Fan 100
H/L	0.28	0.28
R/L	0.11	0.16
β_1	125°	125°
β_2	47°	47°

[0025] In Table 4, the noise value and the number of revolutions are shown at a blown-out airflow amount of 16 m³/min in a case where the sirocco fans 1B and 100 are mounted on the indoor unit 10. All the conditions other than the sirocco fan are the same.

[0026] [Table 4]

Table 4 Noise Value and Number of Revolutions at 16 m³/min

	Sirocco Fan 1B	Sirocco Fan 100
Noise Value (dB)	46.1	47.2
Number of Revolutions (rpm)	1088	1127

[0027] As shown in Tables 3 and 4, by setting R/L = 0.11, the noise value and the number of revolutions can be reduced.

[0028] In Table 5, values of H/L, R/L, β_1 , and β_2 of the sirocco fan 1C of the first embodiment of the present invention and that of the conventional sirocco fan 100 are shown.

[0029] [Table 5]

Table 5 Shape Parameters of Blade

	Sirocco Fan 1C	Sirocco Fan 100
H/L	0.28	0.28
R/L	0.16	0.16
β_1	110°	125°
β_2	47°	47°

[0030] In Table 6, the noise value and the number of revolutions are shown at a blown-out airflow amount of 16 m³/min in a case where the sirocco fans 1C and 100 are mounted on the indoor unit 10. All the conditions other than the sirocco fan are the same.

[0031] [Table 6]

Table 6 Noise Value and Number of Revolutions at 16 m³/min

	Sirocco Fan 1C	Sirocco Fan 100
Noise Value (dB)	46.3	47.2
Number of Revolutions (rpm)	1115	1127

[0032] As shown in Tables 5 and 6, by setting $\beta_1 = 110^\circ$, the noise value and the number of revolutions can be reduced.

[0033] In Table 7, the values of H/L, R/L, β_1 , and β_2 of the sirocco fan 1D of the first embodiment of the present invention and that of the conventional sirocco fan 100 are shown.

[0034] [Table 7]

EP 2 131 041 A1

Table 7 Shape Parameters of Blade

	Sirocco Fan 1D	Sirocco Fan 100
H/L	0.28	0.28
R/L	0.16	0.16
β_1	125°	125°
β_2	29°	47°

[0035] In Table 8, the noise value and the number of revolutions are shown at a blown-out airflow amount of 16 m³/min in a case where the sirocco fans 1D and 100 are mounted on the indoor unit 10. All the conditions other than the sirocco fan are the same.

[0036] [Table 8]

Table 8 Noise Value and Number of Revolutions at 16 m³/min

	Sirocco Fan 1D	Sirocco Fan 100
Noise Value (dB)	46.4	47.2
Number of Revolutions (rpm)	1113	1127

[0037] As shown in Tables 7 and 8, by setting $\beta_2 = 29^\circ$, the noise value and the number of revolutions can be reduced.

[0038] In Table 9, the noise value and the number of revolutions is shown at a blown-out airflow amount of 16 m³/min in a case where the sirocco fan 1 is mounted on the indoor unit 10 and H/L = 0.22, R/L = 0.11, $\beta_1 = 110^\circ$, and $\beta_2 = 29^\circ$, respectively.

[0039] [Table 9]

Table 9 Noise Value and Number of Revolutions at 16 m³/min

	Sirocco Fan 1
Noise Value (dB)	45.3
Number of Revolutions (rpm)	1088

[0040] As shown in Table 9, when optimal H/L, R/L, β_1 , and β_2 are combined, both the noise value and the number of revolutions become minimum.

[0041] Next, descriptions will be given to why the noise value and the number of revolutions are reduced by setting H/L = 0.22, R/L = 0.11, $\beta_1 = 110^\circ$, and $\beta_2 = 29^\circ$.

[0042] In a case where the H/L is greater than 0.26, the warp of the blade increases and the airflow is peeled off from a blade surface at a negative pressure surface side, so that a stall occurs to cause an increase in the noise value and the number of revolutions. On the other hand, in a case where the H/L is smaller than 0.18, the warp of the blade is reduced and a lifting power of the blade is lowered to cause an increase in the noise value and the number of revolutions. In a case where the R/L is greater than 0.11, a stagnation pressure increases and a dynamic pressure is lowered at the front edge of the blade, so that the airflow amount is reduced to cause an increase in the noise value and the number of revolutions.

If the β_1 is greater than 130°, an area of an inflow portion between the blades is reduced to cause an increase in the noise value and the number of revolutions. On the other hand, if the β_2 is smaller than 100°, the incidence angle α of the blade is increased to bring about the stall to cause an increase in the noise value and the number of revolutions.

If the β_2 is greater than 32°, the warp of the blade is reduced and the lifting power is reduced to cause an increase in the noise value and the number of revolutions. On the other hand, if the β_2 is smaller than 26°, an area of an outflow portion between the blades is reduced to cause an increase in the velocity of the airflow at the outflow portion between the blades. Since the airflow between the blades of the sirocco fan is in a stall state to some extent, when the velocity at the outflow portion between the blades is increased, a re-adhesion of the flow that has stalled in the vicinity of the front edge occurs in the vicinity of the rear edge. When the re-adhesion occurs, a fluctuation in the static pressure on a blade surface is increased to cause an increase in the noise.

Second Embodiment

[0043] In the sirocco fan 1 of $H/L = 0.22$, $R/L = 0.11$, $\beta_1 = 110^\circ$, and $\beta_2 = 29^\circ$ shown in the first embodiment, a sirocco fan 1X is defined in such a way that the negative pressure surface side of the front edge is almost linearly cut off as illustrated in Fig. 5. The front edge of the sirocco fan 1 has a shape composed of a semicircular arc.

[0044] In Table 10, the noise value and the number of revolutions are shown at a blown-out airflow amount of $16 \text{ m}^3/\text{min}$ in a case where the sirocco fans 1 and 1X are mounted on the indoor unit 10. All the conditions other than the sirocco fan are the same.

[0045] [Table 10]

Table 10 Noise Value and Number of Revolutions at $16 \text{ m}^3/\text{min}$

	Sirocco Fan 1X	Sirocco Fan 1
Noise Value (dB)	45.3	45.8
Number of Revolutions (rpm)	1088	1103

[0046] As shown in Table 10, if the negative pressure surface side of the front edge formed of the semicircular arc of the sirocco fan is cut off, the noise value and the number of revolutions can be reduced.

[0047] Next, descriptions will be given to the reason. In Figs. 6 and 7, a relative velocity distribution of the airflow inside of the fan in the vicinity of a main plate at 1100 rpm is shown. In Table 11, the static pressure of the fan under a single operation is shown (1100 rpm, and the air-blowing amount $8 \text{ m}^3/\text{min}$).

When comparing the relative velocity distribution inside of the fan of the sirocco fan 1 shown in Fig. 6, and that of the sirocco fan 1X in which the negative pressure surface side of the leading edge is cut off, shown in Fig. 7, the velocity distribution in the vicinity of the front edge at the negative pressure surface side of the sirocco fan 1X is greater. This is because, primarily, the velocity of the blowing air on the negative pressure surface side of the front edge where the a wind easily blows is increased by cutting off the negative pressure surface side, and the number of revolutions and the noise value are reduced as shown in Table 10. Further, from the static pressure shown in Table 11, the highest static pressure can be obtained at the same number of revolutions and air-blowing amount by the sirocco fan 1X in which the negative pressure surface side of the leading edge is cut off, and an effect appears that the wind is easier to blow by cutting off the negative pressure surface side of the front edge.

[0048] [Table 11]

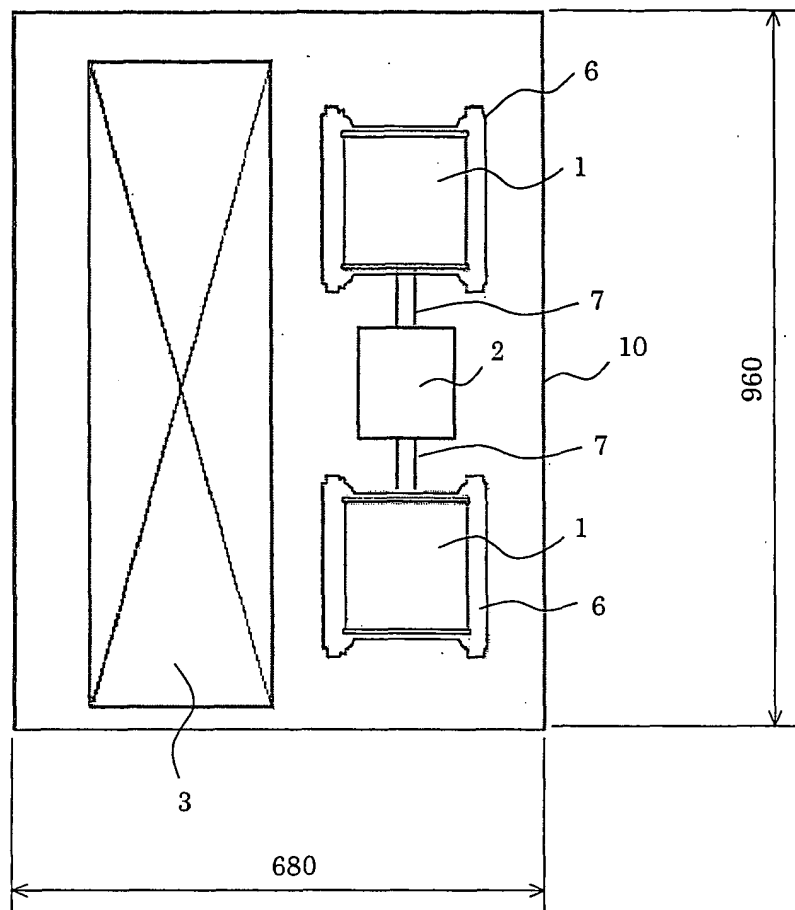
Table 11 Static Pressure at 1100 rpm, $8 \text{ m}^3/\text{min}$

	Sirocco Fan 1X	Sirocco Fan 1
Static Pressure (Pa)	61.3	60.2

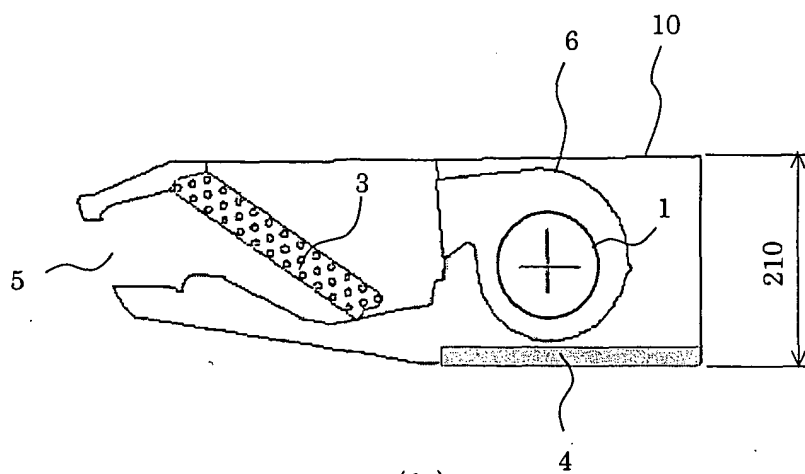
Claims

1. A sirocco fan including: a scroll and a large number of blades being rotatably disposed in the scroll and arranged in a cylindrical manner,
wherein a fan diameter is defined as D , a maximum camber height is defined as H , a blade chord length is defined as L , a radius of a leading edge at an inner circumferential side of the blade is defined as R , a blade inlet angle is defined as β_1 , and a blade exit angle is defined as β_2 , then $0.18 \leq H/L \leq 0.26$, $R/L \leq 0.11$, $100^\circ \leq \beta_1 \leq 130^\circ$, and $26^\circ \leq \beta_2 \leq 32^\circ$ are satisfied.
2. The sirocco fan of Claim 1, wherein the front edge at the inner circumferential side of the blade has a shape in which a negative pressure surface side of the blade is almost linearly cut off from an approximately semicircular arc shape.
3. An air-conditioning apparatus comprising the sirocco fan of any one of Claims 1 through 2.

FIG. 1



(a)



(b)

FIG. 2

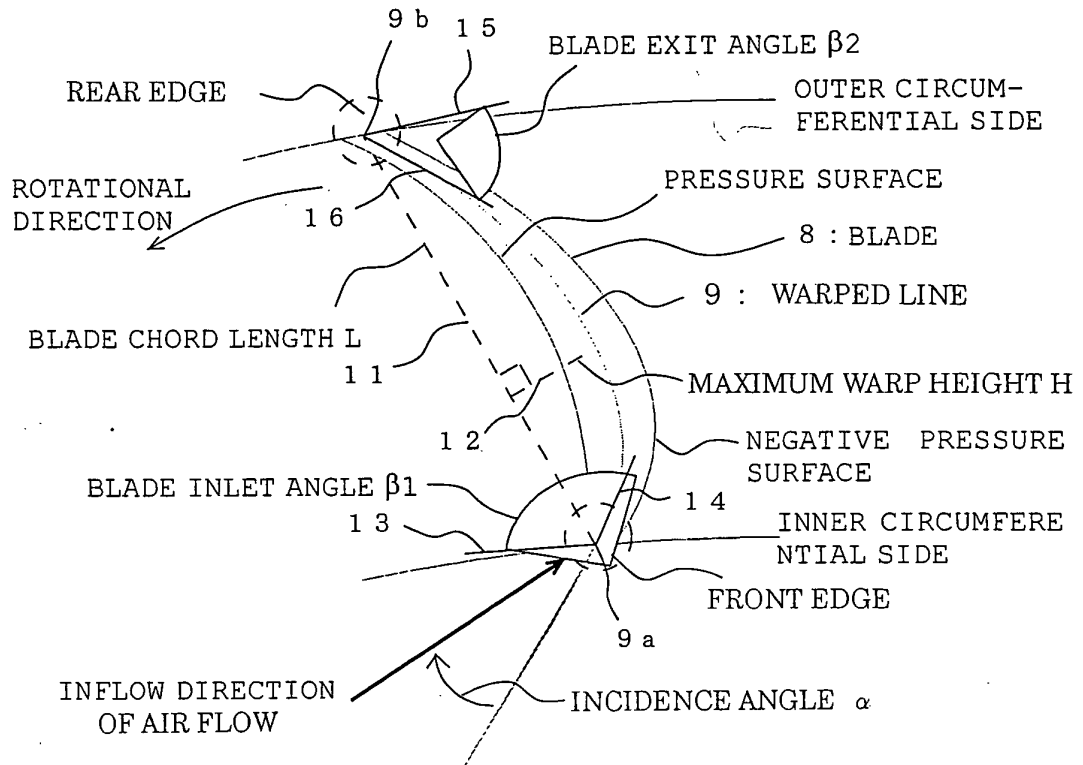


FIG. 3

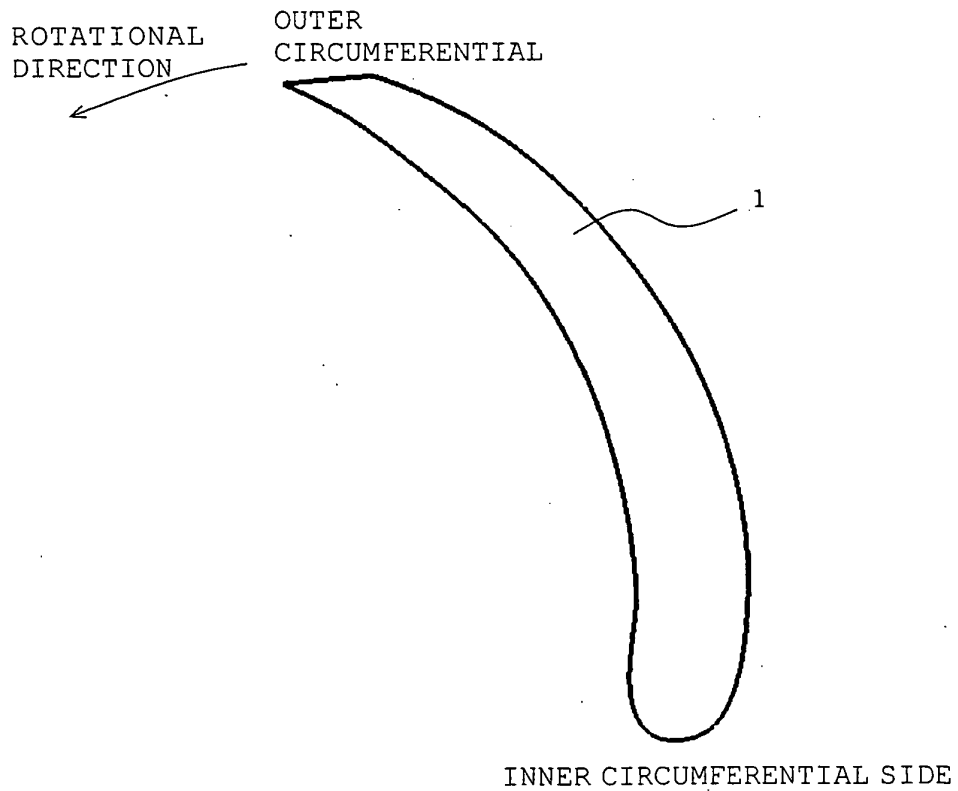


FIG. 4

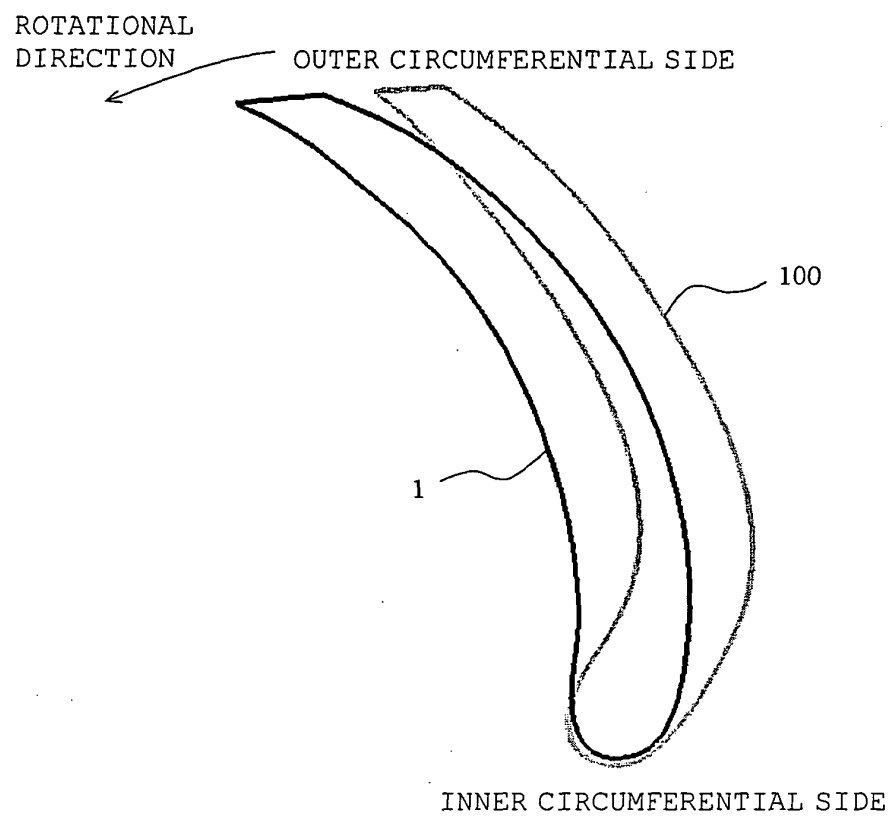


FIG. 5

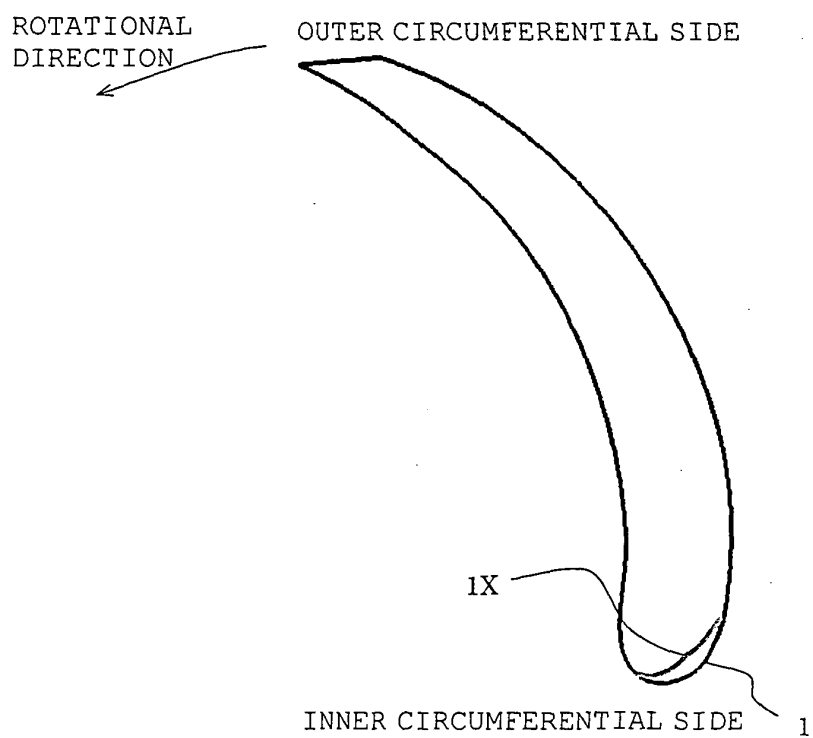
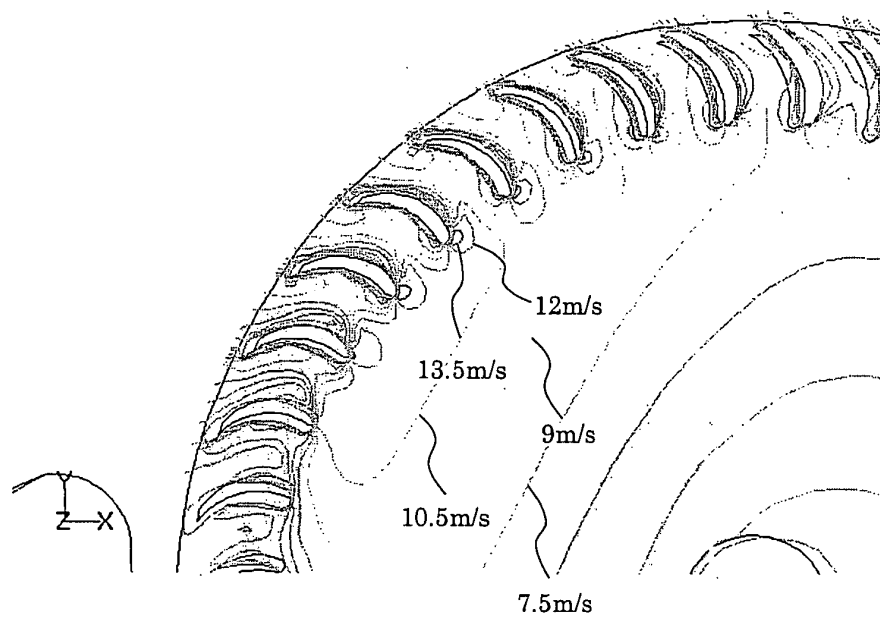
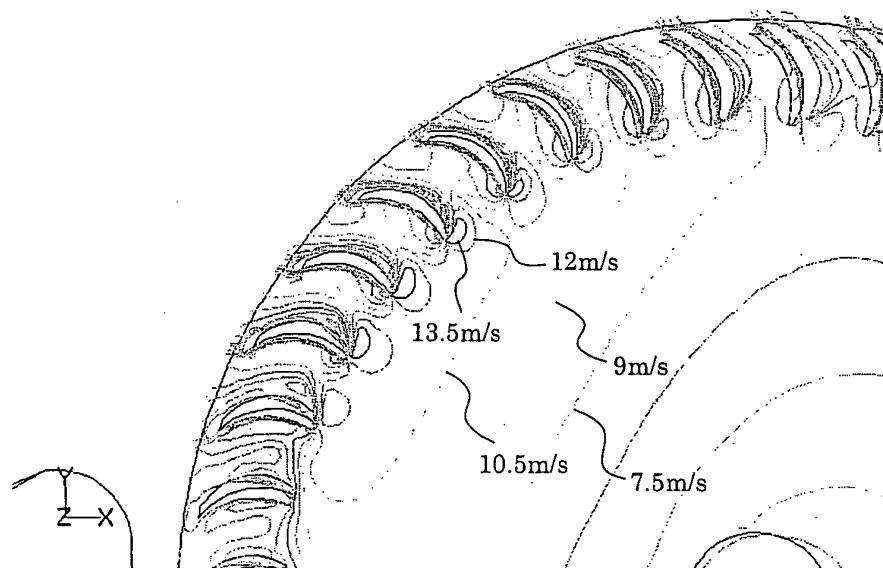


FIG. 6



SIROCCO FAN 1

FIG. 7



SIROCCO FAN 1X

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/055483

A. CLASSIFICATION OF SUBJECT MATTER

F04D29/30(2006.01)i, F04D29/66(2006.01)i, F24F1/00(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)

F04D29/30, F04D29/66, F24F1/00

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	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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.
Y	JP 2006-329097 A (Oriental Motor Co., Ltd.), 07 December, 2006 (07.12.06), Par. Nos. [0012] to [0015]; Figs. 1 to 5 (Family: none)	1-3
Y	JP 1-193099 A (Diesel Kiki Co., Ltd.), 03 August, 1989 (03.08.89), Page 3, lower left column, lines 10 to 18; page 4, lower right column, line 16 to page 5, upper left column, line 4; Fig. 1 (Family: none)	1-3
Y	JP 2000-240590 A (Hitachi, Ltd.), 05 September, 2000 (05.09.00), Par. Nos. [0020] to [0030]; Fig. 1 (Family: none)	1-3

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

* Special categories of cited documents:

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Date of the actual completion of the international search
18 June, 2008 (18.06.08)Date of mailing of the international search report
01 July, 2008 (01.07.08)Name and mailing address of the ISA/
Japanese Patent Office

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Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/055483

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. 53736/1987 (Laid-open No. 160400/1988) (Mitsubishi Motors Corp.), 20 October, 1988 (20.10.88), Page 5, line 16 to page 6, line 7; Figs. 1, 2 (Family: none)	2, 3

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001323895 A [0003]