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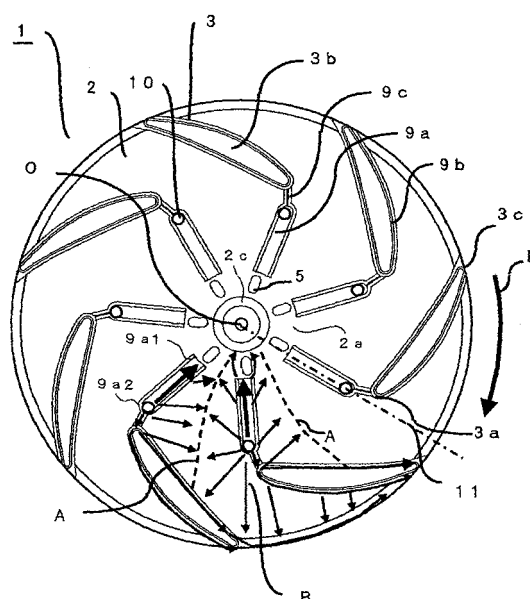
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(54) **TURBO FAN AND AIR CONDITIONER**

(57) The present invention is directed to obtain a turbofan in which a main plate and blades are integrally formed of a thermosetting resin, and which has high reliability in strength and achieves reduced noise. A turbofan includes: a disc-shaped main plate 2; a projected hub 2a for mounting a motor in a space formed by making a center portion of the main plate 2 project in a rotation axis direction; a plurality of blades 3 each of which is vertically provided in the projecting direction of the hub 2a using an outer-periphery-side flat part of the main plate 2 as a base; and a plurality of motor cooling holes 5 which is formed in the hub 2a and communicates with the space in which the motor is mounted. A thermoplastic resin is made to flow in a plurality of hub runners 9a provided radially in the hub 2a, thereby forming the hub 2a, and the motor cooling holes 5 are disposed so as to avoid a resin merging portion A formed between neighboring hub runners 9a.

FIG. 3



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a turbofan molded out of a thermoplastic resin and an air conditioner on which the turbofan is mounted.

Description of the related art

[0002] There is a conventional turbofan molded out of a thermoplastic resin in which rigidity of the turbofan is assured by ribs each constructed by a runner of injected resin to realize lighter weight by reducing the thickness (refer to, for example, Japanese Patent Application No. 3, 131,625 (p. 3 and 4 and FIGS. 1 and 3)).

There is also another turbofan in which the material is decreased by forming a recess in an intersection of a blade and a main plate to realize cost reduction (refer to, for example, Japanese Utility Model Application Laid-open No. 4-116698 (p. 1 and FIG. 1)).

There is further another turbofan including a plurality of blades having similar sectional shapes in which thickness gradually increases from a shroud to a main plate, and the distance between neighboring blades is gradually narrowed from the shroud to the main plate. With the configuration, a time difference is created in release vortices of blowout flows from the shroud to the main plate at a blowout port of the turbofan, thereby preventing noise resonance and the like and reducing noise (refer to, for example, Japanese Patent Application No. 3,544,325 (p. 7 to 9, FIGS. 5 and 6)).

There is further another turbofan using a thick hollow blade, thereby shortening cooling and hardening time at the time of molding, preventing deformation at the time of cooling and hardening, and reducing plastic material (refer to, for example, Japanese Utility Model Application Laid-open No. 4-116699 (p. 1 and FIG. 1)).

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0003] The conventional turbofan in the Japanese Patent Application No. 3,131,625 (p. 3 and 4 and FIGS. 1 and 3) has ribs for reinforcement to realize a thinner main plate, the ribs also serving as a runner of a resin for improvement in moldability.

However, the strength of a resin merging portion, at which resins flowing from the ribs merge at the time of molding, is low. Specifically, the resin merging portion is positioned almost at the same distance from neighboring ribs, and the strength of the portion is low. The conventional turbofan has a blade front-end rib positioned near the front end of a blade and extending in the radial direction, a blade rear-end rib positioned near the rear end of the

blade and extending in the radial direction, a connection rib for connecting the blade front-end rib and the blade rear-end rib, and a blade reinforcement rib. For the ribs, resin is injected from one resin injection port.

5 When the resin injected from the resin injection port flows to the ribs, in each of the blade front-end rib and the blade rear-end rib, the resin flows in two ways in the radial direction to the rotation center side and the outer periphery side. In the connection rib, the resin flows in a direction having a radial-direction component and a circumferential-direction component. In the blade reinforcement rib, the resin flows in the direction opposite to the connection rib. That is, the resin injected from one injection port flows in the plurality of ribs extending in the radial direction. 10 The resins flowing out from the ribs are merged and the resin merging portion is formed. The resin merging portion is also formed between resins flowing out from neighboring resin injection ports. Consequently, a number of resin merging portions are created in the entire of the turbofan, and it limits improvement in strength of the turbofan. Usually, a plurality of holes for cooling a motor are formed in a projected portion of a main plate near the rotation axis. When the resin merging portion is formed on a motor cooling hole as an opening portion having low 15 strength, the strength becomes lower. For example, when an impact in a direction parallel with the rotation axis is applied to the turbofan during transportation or the like, a crack occurs in the resin merging portion around the motor cooling hole. When the portions of low 20 strength are connected, a problem occurs such that the crack extends. With the configuration of the runners, the resin merging portion may extend to the outer peripheral end of the fan. It causes a problem such that the crack occurring in the resin merging portion extends to the outer peripheral end, the fan is easily broken, and the product quality deteriorates. 25

[0004] The configuration described in the Japanese Utility Model Application Laid-open No. 4-116698 (p. 1 and FIG. 1) in which a recess is formed in the intersection 30 of a blade and a main plate has the following problem. A flow along the surface of the main plate is generated when the turbofan rotates. The flow on the surface of the main plate leaves a corner R at the upstream end of the recess and then collides with a corner R at the downstream end, so that noise is generated by pressure fluctuations. 35

[0005] In the turbofan described in the Japanese Patent Application No. 3,544,325 (p. 7 to 9, FIGS. 5 and 6), the blade does not have a hollow structure and the thickness in portions of the blade largely varies, so that a temperature difference occurs in the portions of the blade at the time of molding. Consequently, a cavity is generated due to uneven flow of the resin and local thickness reduction (hereinbelow, called locally small thickness) 40 occurs. It causes a problem that moldability deteriorates. Since the whole blade is made of a resin, as compared with a blade having a hollow shape, a larger amount of resin is necessary. The fan becomes heavy and cost of 45

the fan becomes high. Accordingly, an air conditioner on which the turbofan is mounted becomes heavy. There is a problem that portability for the worker is low.

[0006] A centrifugal fan described in the Japanese Utility Model Application Laid-open No. 4-116699 (p. 1 and FIG. 1) has a thick hollow blade. However, when the blade is too thick, the air passage area of the fan is reduced. Consequently, there is the possibility that noise increases due to increase in passage air velocity. The blade sections perpendicular to the rotation axis are the same. When the blades is released from a mold at the time of performing injection molding, there is no draft. The fan has a problem that the resin is adhered to the mold and breakage occurs.

[0007] The present invention has been achieved to solve the problems as described above, and an object of the invention is to obtain a reliable turbofan which is prevented from being broken at the time of transportation or the like by realizing improvement in moldability and strength of the turbofan made of a thermoplastic resin, and an air conditioner on which the turbofan is mounted. Another object of the invention is to obtain a turbofan realizing reduced noise and an air conditioner on which the turbofan is mounted.

MEANS FOR SOLVING THE PROBLEM

[0008] A turbofan according to the present invention includes: a disc-shaped main plate; a projected hub formed by making a center portion of the main plate project in a rotation axis direction; a plurality of blades each of which is vertically provided in the projecting direction of the hub using an outer-periphery-side flat part of the main plate as a base; a plurality of motor cooling holes which are formed in the hub so as to cool a motor disposed in a space having a projection shape surrounded by the hub; a plurality of hub runners which are provided radially in the hub and into which a thermoplastic resin is made to flow at the time of molding, so as to form the hub; and a resin merging portions each of which is formed by merging the thermoplastic resin flowing out from the neighboring hub runners at the time of molding, and is characterized in that the motor cooling holes are disposed so as to avoid the resin merging portion.

EFFECT OF THE INVENTION

[0009] According to the invention, a fan can be prevented from being broken by an impact because of the configuration that the resin merging portion is not connected to the motor cooling hole. Consequently, the strength can be improved, and an effect that a reliable turbofan can be obtained is produced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIGS. 1A and 1B are plan view and side view, respectively, of a turbofan according to a first embodiment of the invention.

FIG. 2 is a perspective view of the turbofan according to the first embodiment of the invention.

FIG. 3 is a view illustrating the turbofan according to the first embodiment of the invention.

FIG. 4 is an enlarged view illustrating the turbofan according to the first embodiment of the invention.

FIG. 5 is a view illustrating a cross section taken along line H1-H2 of FIG. 4, showing the first embodiment of the invention.

FIG. 6 is an enlarged view illustrating a cross section taken along line O-O1-O2-O3 of FIG. 1B, showing the first embodiment of the invention.

FIG. 7 is a flowchart showing a fan molding process according to the first embodiment of the invention.

FIG. 8 is a graph showing molding time (time from resin injection to taking out after cooling) with respect to the ratio t_1/t_0 of the maximum thickness t_1 of a hub runner 9a and the minimum thickness t_0 of the other portion of a main plate 2 in the first embodiment of the invention.

FIG. 9 is a graph showing molding time (time from resin injection to taking out after cooling) with respect to the ratio t_2/t_0 of the maximum thickness t_2 of a blade runner 9b and the minimum thickness t_0 of the other portion of the main plate 2 in the first embodiment of the invention.

FIGS. 10A and 10B are views showing a blade according to the first embodiment of the invention. FIG. 10A is a side view showing a blade in the fan and FIG. 10B is a view showing a transverse section taken along line Z-Z of FIG. 10A.

FIG. 11 is an explanatory view showing the blade according to the first embodiment of the invention and showing a vertical section taken along line Y-Y of FIG. 10B.

FIG. 12 is a graph showing fan molding time (sec) and noise value (dB) when standing faces on the outside of the blade and on the inside of the hollow are tilted at a tilt angle θ toward the inside of the hollow with respect to the rotation axis and the tilt angle θ is changed.

FIG. 13 is a bottom view showing a turbofan molded with another runner configuration according to the first embodiment of the invention.

FIG. 14 is a bottom view showing a turbofan molded with further another runner configuration according to the first embodiment of the invention.

FIG. 15 is a perspective view showing the turbofan having another configuration, viewed from below, according to the first embodiment of the invention.

FIG. 16 is a partly enlarged perspective view showing a part of the turbofan according to the first embodiment of the invention.

FIGS. 17A and 17B are views illustrating a blade according to the first embodiment of the invention.

FIG. 17A is a side view of a blade in a fan, and FIG. 17B is a view showing a transverse section taken along line Z-Z of FIG. 17A.

FIG. 18A and 18B are views illustrating a blade according to the first embodiment of the invention. FIG. 18A is a view showing a vertical section taken along line Y-Y of FIG. 17B and FIG. 18B is a partially enlarged view of FIG. 18A.

FIG. 19 is a view illustrating a part of the bottom face of the turbofan according to the first embodiment of the invention.

FIG. 20 is a graph showing the relation between the ratio of maximum opening diameter F of a blade opening 3b having a hollow structure to the difference Δt between height of a blade front runner 9ba and height of a blade rear runner 9bb and the noise value with the same air volume according to the first embodiment of the invention.

FIG. 21 is a perspective view showing an air conditioner mounted, viewed from a room according to the first embodiment of the invention.

FIG. 22 is a view showing a vertical cross section of the air conditioner according to the first embodiment of the invention.

FIG. 23 is a view showing a horizontal cross section of the air conditioner according to the first embodiment of the invention.

DESCRIPTION OF REFERENCE NUMERALS

[0011]

1	turbofan
2	main plate
2a	hub
2b	fan inner-radius-side face
2c	boss
2d	hub upper thick portion
3	blade
5	motor cooling hole
8	motor
9	runner
9a	hub runner
9b	blade runner
9ba	blade front runner
9bb	blade rear runner
9c	connection runner
9d	cooling hole runner
10	resin injection port
12	air conditioner body
15	heat exchanger
A	resin merging portion
B	resin flowing direction at the time of molding
C	air current near blade opening
D	fan rotating direction
E1, E2	air currents
F	maximum opening width of blade opening 3b (diameter of inscribing circle of opening in

	main plate)
G	air guided toward motor cooling hole via hub runner
O	rotation center

DESCRIPTION OF THE PREFERRED EMBODIMENT

First Embodiment

[0012] A turbofan (hereinafter, simply called a fan) according to a first embodiment of the present invention will be described hereinafter with reference to the drawings. FIG. 1A is a plan view of a fan according to the embodiment viewed from a shroud side, and shows a blade by partly cutting the shroud away. FIG. 1B is a side view of the fan of FIG. 1A. The left half of FIG. 1B shows a side face, and the right half shows a longitudinal section taken along O-O1-O2-O3 of FIG. 1A.

FIG. 2 is a perspective view showing an under face of the fan according to the embodiment, that is, viewed from the side opposite to the shroud.

[0013] As shown in FIGS. 1A and 1B and FIG. 2, a fan 1 is constructed by a disc-shaped main plate 2. A center portion of the main plate 2 has a projected shape which is projected in the rotation axis direction, and a motor (not shown) is disposed in the space surrounded by the projection. The projection will be called a hub 2a. A boss 2c is formed in the center of the hub 2a, that is, in the center of the main plate 2, and the shaft of a motor is fixed to the boss 2c. A portion in which the motor is mounted is called a fan outside of the main plate 2. In a flat plate portion on the outer peripheral side of the fan inside opposite to the fan outside, a plurality of, for example, seven blades 3 are provided. In a portion connected to the boss 2c of the main plate 2, a hub upper thick portion 2d is provided, which is thicker than a thickness t_0 of an inclined face of the hub 2a.

[0014] The blade 3 uses, as a base portion, a flat portion on the outer peripheral side of the main plate 2 and has a hollow bag shape which is upright from a blade opening 3b in the base portion in the projection direction of the hub 2a. In the base portion, a blade opening 3b is positioned between a blade inner-radius-side end 3a and a blade outer-radius-side end 3c. A center line 3a-3c of the blade opening 3b and the radius of the main plate 2 are disposed so as to intersect at a predetermined angle of, for example, about 45° . As shown in FIG. 1A, a plurality of blades 3 are disposed at variable pitches so that at least part of circumferential-direction mounting pitch angles $\sigma_1, \sigma_2, \sigma_3, \dots$, and σ_7 with respect to the rotational axis varies. In FIG. 1A, for example, $\sigma_1 = \sigma_4 < \sigma_3 = \sigma_6 = \sigma_7 < \sigma_2 = \sigma_5$.

[0015] The fan 1 is driven by the motor and rotates in the direction of the arrow D around a rotation center O. A shroud 4 is provided around the fan 1 as shown in FIG. 1B and is fixed to each of the blades 3 from above in FIG. 1B.

[0016] A fan internal air duct 6 is formed by being sand-

wiched between the shroud 4 and the main plate 2 near the hub 2a, and a fan external air duct 7 is constructed by the hub 2a on the side where motor is disposed. In the hub 2a, motor cooling holes 5 which are constituted of a plurality of openings are formed at almost equidistant positions from the rotation center O around the rotation center O, thereby providing communication between the fan internal air duct 6 and the fan external air duct 7. In FIG. 1A, for example, seven motor cooling holes 5 are provided. Each of the motor cooling holes 5 is arranged on a straight line O-3a connecting one blade inner-radius-side end 3a and the rotation center O. Like the blades 3, the plurality of motor cooling holes 5 are also formed so that at least part of circumferential-direction mounting pitch angles $\gamma_1, \gamma_2, \gamma_3, \dots$, and γ_7 of the plurality of motor cooling holes 5 varies. In this case, the circumferential-direction mounting pitch angles $\gamma_1, \gamma_2, \gamma_3, \dots$, and γ_7 of the motor cooling holes 5 are set as, for example, $\gamma_1 = \gamma_4 < \gamma_3 = \gamma_6 = \gamma_7 < \gamma_2 = \gamma_5$ in a manner similar to the circumferential-direction mounting pitch angles σ of the blades 3.

[0017] The main plate 2 and the blades 3 are integrally molded by using a thermoplastic resin such as ABS or ASG (hereinbelow, simply called resin). In FIG. 2, reference numeral 10 denotes a mark of a resin injection port used for injecting the resin at the time of molding the main plate 2 and the blades 3. The mark 10 is positioned near a folding part between the hub 2a and the flat part of the main plate 2 and near the blade inner-radius-side end 3a in the flat part and will be called a resin injection port 10. Runners 9 serving as paths of the resin at the time of molding are formed in the fan. In a mold, the runner 9 corresponds to a portion which is a space larger in the thickness direction than main parts of the main plate 2 so that the resin can pass easily. In the fan as a finished article, the resin in the runner 9 is solidified and remains, and the thickness of the runner portion is larger than the minimum thickness t_0 of the portion other than the runner in the main plate 2.

[0018] One of the runners 9 is a hub runner 9a for forming the hub at the time of molding. For example, seven hub runners 9a are radially formed in the hub 2a and extend linearly in the radial direction of the fan from the resin injection ports 10 toward the rotation center O without crossing other runners to positions near the motor cooling holes 5. The hub runner 9a is thicker than the minimum thickness t_0 in the inclined face of the hub 2a and has a predetermined thickness t_1 ($> t_0$). The motor cooling holes 5 are disposed near ends on the fan center side of the hub runners 9a, and the blade inner-radius-side ends 3a of the blades 3 are disposed near the other ends on the outer radius side of the fan of the hub runners 9a. Further, a center line 11 in the width direction of each of the linear hub runners 9a is arranged so as to extend on the motor cooling hole 5. The blade inner-radius-side end 3a, the resin injection portion 10, the hub runner 9a, and the motor cooling hole 5 are disposed so as to position on an almost straight line extending in the radial

direction using the rotation center O as a start point. In the embodiment, the mounting pitch angles σ in the circumferential direction of the blades 3 are set as unequal pitch angles, so that the motor cooling holes 5, the hub runners 9a, and the resin injection ports 10 are similarly formed at unequal pitches with respect to the rotation center O. When the mounting pitch angles σ of the blades 3 are identical pitch angles, the mounting pitch angles in the circumferential direction of the motor cooling holes 5, the hub runners 9a, and the resin injection ports 10 are similarly identical pitch angles.

[0019] In the outer-radius-side flat plate portion of the main plate 2 as the base of the hollow blade 3, a blade runner 9b is formed around the blade opening 3b. The blade runner 9b is a runner for forming the blade 3 when the resin is made to flow in at the time of molding. Like the hub runner 9a, the blade runner 9b has a predetermined thickness t_2 ($> t_0$) larger than the thickness t_0 of the outer-radius-side flat plate portion of the main plate 2. A connection runner 9c is a runner for connecting the hub runner 9a and the blade runner 9b. The connection runner 9c is formed, for example, with the same thickness t_1 as that of the hub runner 9a and a width smaller than that of the hub runner 9a and that of the blade runner 9b.

[0020] When the fan 1 rotates in the direction D, the ambient air is guided into the blades 3 by the shroud 4 and sucked to the inside of the shroud 4, passes through a fan internal air duct 6, and blows out from spaces between the blades 3 at the periphery of the fan as shown by the arrows E1 in FIG. 2. At this time, the pressure in a fan internal air duct 6 is negative with respect to the pressure in a fan external air duct 7 in which the motor is attached. As shown in FIGS. 1B and 2, a part E2 of the air blowing out from the fan 1 passes through the motor cooling holes 5 connecting the fan internal air duct 6 to the fan external air duct 7 and flows in the fan external air duct 7 while turning due to friction with the hub 2a. The part E2 of air current passes through the motor cooling holes 5 and flows in the fan internal air duct 6 under negative pressure. A motor is mounted on the side of the fan external air duct 7 surrounded by the hub 2a and fixed to the fan 1 at the boss 2c. With the air current E2, the motor is cooled.

[0021] At the time of integrally molding the turbofan with such a configuration by using a resin, the resin is injected from the plurality of resin injection ports 10 to a mold having a space of a fan shape. The resin injected from the resin injection ports 10 is led to the runners 9 as thick portions, flows in the whole fan, and the main plate 2 and the blades 3 are integrally formed. FIG. 3 is a bottom view of the fan. The hub runners 9a are runners each provided between a center-side end 9a1 to a fan outer-radius-side end 9a2. The motor cooling holes 5 are disposed near the fan center-side ends 9a1 and the blade inner-radius-side ends 3a are disposed near the fan outer-radius-side ends 9a2.

A part of the resin flows in the hub runners 9a and, after that, flows in the hub 2a in the main plate and forms the

portion. Another part flows from the connection runners 9c to the blade runners 9b, flows to the blades 3 and the main plate 2 around the blades 3, and forms the portions. The flow of resin is shown by the arrow B in FIG. 3. The resin flows via the runners 9 to the mold as shown by the arrows B, and the resin flowing from neighboring runners 9 collides and merges at a resin merging portion located so as to be almost equidistant from the neighboring runners. The resin merging portion is indicated by a broken line A.

[0022] The resin injected from the resin injection ports 10 and led to the hub runners 9a flows smoothly in one direction toward the rotation center O in the radial direction. Further, the resin flowing in a hub runner 9a flows toward a neighboring hub runner 9a, so that a resin merging portion A is formed between neighboring hub runners 9a. Since the motor cooling holes 5 are arranged so as to avoid resin merging portions A, a resin merging portion A near a motor cooling hole 5 is formed, not in connection with the motor cooling hole 5, but between the neighboring motor cooling holes 5.

Since the resin merging portion A is not coupled to the motor cooling hole 5 as an opening having low strength against impact, occurrence of a crack connected to the motor cooling hole 5 and the resin merging portion A can be prevented, and the strength of the molded fan 1 can be improved. Therefore, even if an impact is applied in the direction of the rotation axis of the fan 1 at the time of transportation or the like, for example, in the vertical direction of FIG. 1B and a crack occurs in the periphery of the motor cooling hole 5, extension of the crack in the radial direction of the main plate 2 can be prevented. Consequently, the fan 1 can be prevented from being broken, and reliability against the impact on the fan 1 can be improved.

In particular, in the embodiment, by forming the motor cooling hole 5 on the extension line of the hub runner 9a, formation of the resin merging portion A near the motor cooling hole 5 can be surely avoided.

[0023] The runners 9 are not complicatedly branched. A runner 9 is branched to two runners; the hub runner 9a, and the connection runner 9c at the resin injection port 10, and is branched into the blade runner 9b in two directions at the connection part of the connection runner 9c and the blade runner 9b. Since the strength is low in the resin merging portion A as described above, it is preferable to set the number and length of the resin merging portions A as small as possible. In the configuration of the runners 9 according to the embodiment, the resin merging portion A is not formed by the resin injected from the one resin injection port 10 but is formed by the contact portion of the resin injected from the neighboring resin injection ports 10. Consequently, the number of the resin merging portions A can be decreased as a whole. As described above, the runners 9 are constructed relatively simply, the resin flows along the runners 9 more easily, occurrence of shrinkage is reduced, and moldability can be improved.

[0024] Further, in the fan according to the embodiment, one end of the resin merging portion A is in contact with the boss 2c.

The resin merging portion A extends in the radial direction between the neighboring motor cooling holes 5. The other end is in contact with the center of the blade 3. In the conventional configuration in which the resin merging portion A extends straight to the outer periphery, in the case where a crack occurs along the resin merging portion A, there is the possibility that the crack extends to the outer periphery of the fan 1 and the fan 1 is broken down. In contrast, in the embodiment, the outer-radius-side end of the resin merging portion A formed in the main plate 2 is in contact with the blade runner 9b.

Consequently, the resin merging portion A formed in the main plate 2 can be made shorter, that is, the portion with low strength can be shortened. Thus, the fan 1 with high reliability in strength can be obtained. Even if a crack occurs near the resin merging portion A and extends along the resin merging portion A at the time of transportation or the like, since the outer-radius-side end of the resin merging portion A is in contact with the thick blade runner 9b, the crack stops at this part. Further, in the case where the crack does not stop by the blade runner 9b, the whole blade 3, which is connected to the blade runner 9b and has height in the axial direction, serves as a strength member. Consequently, the fan 1 can be prevented from being completely broken down, and reliability against an impact can be improved.

[0025] The configuration of the resin merging portion A and the runners 9 will be described in detail hereinbelow. The number of pieces, the shape, and the angle with respect to the radius of the blades 3, the shape and configuration of the runners 9, the positions of the resin injection ports 10, the shape and position of the motor cooling hole 5, and the like are set as described above. That is, one end of the resin merging portion A is in contact with the boss 2c, the resin merging portion A extends in the radial direction between the neighboring motor cooling holes 5, and the other end is in contact with the center of the blade 3. With the configuration, the fan 1 having reliability against an impact can be obtained.

FIG. 4 is a partly enlarged view of FIG. 3. FIG. 5 is a view illustrating a cross section taken along line H1-H2 of FIG. 4. The resin injection port 10 is provided, for example, in the hub runner 9a at a position close to the connection runner 9c. Two neighboring resin injection ports 10m and 10n will be described as an example. The resin injection port 10m is connected to a hub runner 9am, a blade runner 9bm, and a connection runner 9cm. The resin is injected from the resin injection port 10m to mold the blade 3m and the main plate 2 around the blade 3m. On the other hand, a resin injection port 10n is connected to a hub runner 9an, a blade runner 9bn, and a connection runner 9cn. The resin is injected from the resin injection port 10n to mold the blade 3n and the main plate 2 around the blade 3n. The blade 3 formed upright on the main plate 2 has a predetermined thickness t_3 ($> t_0$) and the

thickness in the blade 3 is almost uniform.

[0026] In the case where the blade 3m is positioned ahead of the blade 3n in the fan rotation direction (the arrow D direction), to prevent the resin merging portion A formed between the two blades 3m and 3n from being connected to the fan outer periphery, the area L should be formed with the resin injected from the resin injection port 10n. In particular, when the resin injected from the resin injection port 10n, not the resin injected from the resin injection port 10m, is used as the resin for forming a flat part 3cmt of the blade outer-radius-side end of the blade 3m, the resin merging portion A formed between the hub runners 9an and 9am is surely brought in contact with the blade 3m. To realize it, the runners 9 should be constructed so that the distance from the resin injection port 10n is shorter than the distance from the resin injection port 10m with respect to the lengths of the flow paths of the resin flowing to the flat part 3cmt at the blade outer periphery.

[0027] Concretely, the number of pieces and the shape of the blades 3, the shape and configuration of the runners 9, the positions of the resin injection ports 10, the shape and position of the motor cooling hole 5, resin injection speed, and the like, are fittingly set and, for example, a simulation is performed. In such a manner, a part in which the resin merging portion A is to be formed in the fan at the time of molding can be examined. The configuration should be so constructed that one end of the resin merging portion A obtained by the simulation comes in contact with the boss 2c and extends in the hub 2a between the neighboring motor cooling holes 5, and the other end comes in contact with the blade runner 9b.

[0028] As described above, the turbofan includes: the disc-shaped main plate 2; the projected hub 2a formed by making a center portion of the main plate 2 project in the rotation axis direction; the plurality of blades 3 each using the outer-periphery-side flat part of the main plate 2 as the base and vertically provided in the projecting direction of the hub 2a; the plurality of motor cooling holes 5 formed in the hub 2a and for cooling a motor disposed in a space having a projection shape surrounded by the hub 2a; the plurality of hub runners 9a which are provided radially in the hub 2a and into which a resin is made to flow at the time of molding, thereby forming the hub 2a; and the resin merging portion A formed by merging the resin flowing out from the neighboring hub runners 9a at the time of molding. By disposing the motor cooling holes 5 so as to avoid the resin merging portion A, there is an effect that the turbofan having high reliability against an impact can be obtained.

[0029] The plurality of motor cooling holes 5 provided in the hub 2a is disposed at portions on extended lines of the hub runners 9a to the rotation center O so that coupling between the motor cooling holes 5 having low strength to impact and the resin merging portion A is surely prevented, and the fan having high reliability against an impact is obtained.

[0030] By forming the hub runners 9a radially around

the rotation center O, the resin flows to the boss 2c around the rotation center more easily, and moldability can be improved

[0031] Each runner 9 as a path of the resin is formed so as to be separated to a hub runner 9a and a blade runner 9b. A connection runner 9c for connecting the runners 9a and 9b is provided and, further, the resin is injected from the resin injection port 10 provided in any one of the runners 9a, 9b, and 9c. Specifically, either of the resin flowing in the hub runner 9a and the resin flowing in the blade runner 9b necessarily flows via the connection runner 9c. Consequently, the balance between the amount of the resin flowing in the hub runner 9a and that of the resin flowing in the blade runner 9b can be adjusted according to settings of the width and thickness of the connection runner 9c. By adequately adjusting the injection amounts of the resin flowing in the hub runner 9a and the blade runner 9b, occurrence of cavity or locally small thickness due to uneven flow can be prevented, and deterioration in strength can be prevented.

Although the resin injection port 10 is directly provided in the hub runner 9a in the embodiment, the resin injection port 10 may be provided in the blade runner 9b or the connection runner 9c. In the case of providing the resin injection port 10 in the connection runner 9c, by making the thickness and width of the runner between the resin injection port 10 and the hub runner 9a and those of the runner between the resin injection port 10 and the blade runner 9b different from each other in accordance with the flow rate of resin required, the balance of the resin amounts can be adjusted.

[0032] Since the blade 3 has the hollow shape and the blade opening 9b is provided around the opening 3b, the weight can be reduced because of the hollow shape, and the resin runs to the whole mold more easily at the time of molding the blades 3.

Consequently, the blade 3 can be made thinner and lighter. By the reduction in weight, the weight in the fan peripheral portion with respect to the rotation center is reduced. Therefore, the centrifugal force at the time of rotation is reduced and a stress applied to the root of the main plate as the base of the blade 3 is reduced. As a result, the strength of the fan 1 can be improved, and breakage at the time of rotation can be prevented. Since the portion of the blade runner 9b remains as the resin in a molded body, the thickness of the connected part of the blade 3 and the main plate 2 on which stress is concentrated can be increased by the blade runner 9b. As described above, the resin flowability is improved by the blade runner 9b, moldability can be improved, and strength of the turbofan can be improved.

[0033] As described above, by providing the plurality of hub runners 9a which are provided radially in the hub 2a and in which a resin is made to flow at the time of molding, thereby forming the hub 2a; the plurality of blade runners 9b which are respectively provided around the bases of the blades 13 and in which the resin is made to flow at the time of molding, thereby forming the blade 3;

and the connection runners 9c for respectively connecting the hub runners 9a and the blade runners 9b positioned close to the respective hub runners 9a, each of the runners 9 is continuously formed in the radial direction from the rotation center side to the outer periphery of the main plate 2. Consequently, the resin injected from the resin injection port 10 is branched to the resin flowing toward the rotation center and the resin flowing toward the outer periphery side in main flow directions. After that, the resin does not flow backward but flows to the main plate 2 in the periphery while flowing through the runners 9.

As described above, the resin flow directions are relatively simple, so that a portion in which the resin merging portion A is formed can be predicted clearly. There are also effects that the resin can flow smoothly, moldability can be improved, and the very reliable fan 1 can be obtained. Further, the distance of the resin merging portion A can be shortened, and deterioration in the strength of the turbofan can be prevented.

[0034] As compared with the conventional configuration in which the resin merging portions are formed by the resin injected from a single resin injection port, in the embodiment, the number of the resin merging portions A can be decreased, the mold design can be simplified, and occurrence of cavity and locally small thickness due to uneven flow can be prevented.

[0035] FIG. 6 is a partly enlarged view of FIG. 1B. As shown in the figure, in the fan according to the embodiment, the hub runner 9a having the thickness t_1 is projected from the hub 2a having the thickness t_0 to the fan external air duct 7 side only by the thickness difference ($t_1 - t_0$) in the wall face constructing the hub 2a of the fan external air duct 7. The motor cooling hole 5 is positioned on the extension line of the hub runner 9a on the rotation center side. Consequently, the hub runner 9a functions as an air guiding plate and induces air current G toward the motor cooling hole 5. The hub runner 9a serves as an air guiding plate to the air current G, thereby increasing the current of air flowing on the surface of a motor mounted in the portion surrounded by the hub 2a and accelerating cooling of the motor. Usually, temperature protection control is performed such that power supply to the motor is stopped when the temperature increases to certain temperature in temperature rise of the motor. However, by accelerating cooling of the motor, the motor can be efficiently driven without executing the temperature protection control. Further, breakage of the motor caused by the high temperature of the motor can be also prevented.

[0036] As described above, by the projection of the hub runner 9a from the face of the main plate 2 of the hub 2a to the fan external air duct 7 side as the motor mounting side, the current of air to the surface of the motor is increased, cooling of the motor can be accelerated, and there is an effect that the very reliable turbofan can be obtained.

[0037] With respect to the shape of the fan according

to the embodiment, a plurality of sets each constructed by the blade 3, the blade runner 9b, the hub runner 9a, the connection runner 9c, and the motor cooling hole 5 are provided radially around the rotation axis O as a center. Specifically, all of the blades 3 constructing the fan 1 have almost the same arrangement that the resin injection port 10, the hub runner 9a, the blade runner 9b, the connection runner 9c, and the motor cooling hole 5 are prepared for the blade. Therefore, by injecting almost the same amount of resin to the plurality of resin injection ports 10, the resin flows in similar directions in the entire disc-shaped fan 1, and the blades 3 can be formed under similar molding conditions. Consequently, there is an effect such that, in a fan completed by molding, occurrence of cavity and locally small thickness caused by uneven flow can be prevented as a whole, and a turbofan having high reliability in strength is obtained.

For example, when the necessary resin amount is different among the sets each constructed by the blade 3, the blade runner 9b, the hub runner 9a, the connection runner 9c, and the motor cooling hole 5 due to, for example, variations in the pitches in the circumferential direction, by changing the amount of resin injected from the resin injection port 10 in accordance with the necessary amount, the molding can be performed under similar molding conditions, and an effect similar to the above is produced.

[0038] By providing equal numbers of the motor cooling holes 5 and the hub runners 9a, the disposal relation of the blade 3 to the motor cooling hole 5 can be made almost similar to the motor cooling holes 5 constructing the fan 1. Consequently, turbulent air flow E2 from the fan external air duct 7 to the fan internal air duct 6 via the motor cooling hole 5 goes to the rear side of the blade 3 formed by the blade runner 9b connected to the hub runner 9a closest to the motor cooling hole 5. The turbulent air flows E2 from the motor cooling holes 5 flow between the blades 3 and 3 respectively and they do not directly collide with each other. Therefore, without being subjected to large pressure fluctuations, the turbofan realizing reduced noise can be obtained.

Although equal numbers of the motor cooling holes 5 and the hub runners 9a are provided here, the number of motor cooling holes 5 may be smaller than that of the hub runners 9a. For example, the motor cooling holes 5 may not be provided on the rotation center O side of all of the hub runners 9a. By providing the motor cooling holes 5 in positions avoiding the resin merging portions A of the hub 2a and in uniform positions with respect to the rotation center O, the turbofan having high reliability in strength, which can be molded under substantially uniform molding conditions and in which occurrence of cavity and locally small thickness due to uneven flow can be prevented as a whole, is obtained. Obviously, by providing equal numbers of the motor cooling holes 5 and the hub runners 9a, the turbofan can be molded under more uniform molding conditions, and the very reliable turbofan is obtained.

[0039] The fan shape is so constructed as shown in FIG. 1 that a plurality of sets each made of the blade 3, the blade runner 9b, the hub runner 9a, the connection runner 9c, and the motor cooling hole 5 are provided radially around the rotation axis O as a center, and at least one of angles each formed between neighboring sets is different from the other angles. With the configuration, the air current E2 released to the outside from the motor cooling hole 5 and the air flow E1 blowing off from the blade 3 are prevented from having periodicity. Therefore, noise due to the number of revolutions of the fan can be prevented and quietness in the sense of hearing is maintained.

[0040] As described above, by providing a plurality of sets each constructed by the blade 3, the blade runner 9b, the hub runner 9a, the connection runner 9c, and the motor cooling air 5 radially arranged around the rotary shaft as a center, each of the blades 3 has almost the same arrangement with respect to the resin injection port 10, the hub runner 9a, the blade runner 9b, and the motor cooling hole 5. Therefore, the molding conditions can be made almost the same, occurrence of cavity and locally small thickness caused by uneven flow can be prevented, and the turbofan having high reliability in strength is obtained.

In the sets each constructed by the blade 3, the blade runner 9b, the hub runner 9a, the connection runner 9c, and the motor cooling hole 5, by making at least one of the angles each formed between neighboring sets different from the other angles, an effect that noise can be reduced is obtained.

[0041] By providing the motor cooling holes 5 of the same number as that of the hub runners 9a, the positional relations between the motor cooling holes 5 and the blades 3 can be made equal, the air current E2 flowing from the fan external air duct 7 to the fan internal air duct 6 can smoothly pass between the blades and to the outside. Effects that noise can be reduced and, further, moldability is high are produced.

[0042] A fan molding process will now be described with reference to FIG. 7. FIG. 7 is a flowchart showing the fan molding process. A mold for molding the fan 1 having the shape shown in FIGS. 1 to 6 is fixed (ST1), and the thermoplastic resin is injected from the resin injection ports 10 (ST2). The injected resin flows through the hub runners 9a, the connection runners 9c, and the blade runners 9b and, further, spreads from the runners 9 to the main plate 2 and the blades 3. The whole fan is filled with the resin in a few msec. Next, the fan is cooled to harden the thermoplastic resin (ST3). After the thermoplastic resin is completely hardened, the molded fan 1 is released and removed from the mold (ST4). After that, the shroud 4 is fixed to the suction side of the fan 1 (ST5). Further, the program advances to a process such as attachment of the shaft of a motor.

[0043] The thicknesses of the parts of the resin forming the fan 1 will now be described.

As shown in FIGS. 5 and 6, the minimum thickness of

the part other than the runners 9 of the main plate 2 is t_0 , the thickness of the hub runner 9a is t_1 , the thickness of the blade runner 9b formed around the opening 3b of the blade having a hollow shape is t_2 , and the thickness of the blade 3 having a hollow shape is t_3 . At least the thicknesses t_1 , t_2 , and t_3 are set to be larger than the thickness t_0 . Although there is a case that the runners 9 have an error at the time of molding or their corner portion has an R shape, a portion having the maximum thickness is set as the thickness of the runner 9. As shown in the diagrams, the thicknesses of the runners 9 include the thickness of the main plate 2 and the thickness of the portion projected from the main plate face.

FIG. 8 is a graph showing molding time with respect to the ratio t_1/t_0 of the thickness t_1 of the hub runner 9a to the minimum thickness t_0 of the portion other than the runner in the main plate 2. The axis of abscissa shows t_1/t_0 , and the axis of ordinate indicates the molding time (sec). The molding time denotes time required for ST2 to ST4 in the flowchart shown in FIG. 7, which is the time from the resin injection to the removing from the mold after cooling.

[0044] As shown in the graph of FIG. 8, in the case where t_1/t_0 is 1.0 or less, that is, the thickness t_1 of the hub runner 9a is equal to or less than the minimum thickness t_0 of the portion other than the runners in the main plate 2, the runner 9a is thinner, flow of the resin is not good, it takes time for the resin to flow in the whole mold, and molding time increases. In the case where t_1/t_0 is larger than 2.0, that is, the thickness t_1 of the hub runner 9a is larger than twice as large as the minimum thickness t_0 of the portion other than the runners in the main plate 2, it takes time to cool down the resin, and the time until removing increases. As a result, when the ratio t_1/t_0 lies in the range of $1.1 \leq t_1/t_0 \leq 2$, the molding time can be made shorten at least more than the case where the thicknesses t_1 and t_0 are the same ($t_1/t_0 = 1.0$). By shortening the molding time, the production amount can be increased. Further, electricity used by a molding machine can be also reduced so that energy can be saved.

[0045] FIG. 9 is a graph showing molding time with respect to the ratio t_2/t_0 of the thickness t_2 of the blade runner 9b to the minimum thickness t_0 of the portion other than the runners in the main plate 2. The axis of abscissa shows t_2/t_0 , and the axis of ordinate indicates the molding time (sec). The molding time denotes time required for ST2 to ST4 in the flowchart shown in FIG. 7, which is the time from the resin injection to the removing after cooling. As shown in the graph of FIG. 9, in the case where t_2/t_0 is 1.0 or less, that is, the thickness t_2 of the blade runner 9b is equal to or less than the minimum thickness t_0 of the portion other than the runners in the main plate 2, the runner 9b is thinner, flow of the resin is not good, it takes time for the resin to flow in the whole mold, and molding time increases. In the case where t_2/t_0 is larger than 2.0, that is, the thickness t_2 of the blade runner 9b is larger than twice as large as the minimum thickness t_0 of the portion other than the runners in the main plate 2, it takes

time to cool down the resin, and the time until removing increases. As a result, when the ratio t_2/t_0 lies in the range of $1.1 \leq t_2/t_0 \leq 2$, the molding time can be made shorten at least more than the case where the thicknesses t_2 and t_0 are the same ($t_2/t_0 = 1.0$). By shortening the molding time, the production amount can be increased. Further, electricity used by a molding machine can be also reduced so that energy can be saved.

[0046] Therefore, by setting the ratio t_1/t_0 between the thickness t_1 of the hub runner 9a and the minimum thickness t_0 of the portion other than the runners 9 in the main plate 2 in the range of $1.1 \leq t_1/t_0 \leq 2$, the molding time can be shortened as compared with the case where the thicknesses t_1 and t_0 are the same ($t_1/t_0 = 1.0$). Similarly, by setting the ratio t_2/t_0 between the thickness t_2 of the blade runner 9b and the minimum thickness t_0 of the portion other than the runners 9 in the main plate 2 in the range of $1.1 \leq t_2/t_0 \leq 2$, the molding time can be shortened as compared with the case where the thicknesses t_2 and t_0 are the same ($t_2/t_0 = 1.0$). Particularly, by setting the upper limit of the thicknesses t_1 and t_2 of the runners 9 to double of the minimum thickness t_0 of the main plate 2, the molding time can be shortened, the amount of the resin can be decreased, and reduction in the weight and cost of the fan 1 can be also achieved.

Although the thickness t_1 of the hub runner 9a and the thickness t_2 of the blade runner 9b have been described separately, it is also possible to satisfy one of the thicknesses or both of them. In the configuration where both of the thicknesses t_1 and t_2 are satisfied, the molding time can be further shortened effectively.

[0047] As described above, when at least one of the thickness of the hub runner 9a and the thickness of the blade runner 9b is set as " t " and the thickness of the portion other than the runners 9 in the main plate 2 is t_0 , by setting the ratio t/t_0 to be in the range of $1.1 \leq t/t_0 \leq 2$, the molding time can be shortened as compared with the case where the thicknesses t and t_0 are the same ($t/t_0 = 1.0$).

[0048] The shape of the blade 3 will be described hereinbelow.

FIGS. 10A and 10B and FIG. 11 show the configuration of one blade 3. FIGS. 10A and 10B and FIG. 11 are diagrams illustrating the blade 3 according to the embodiment. FIG. 10A is a side view of one blade. FIG. 10B is a view illustrating a transverse section taken along line Z-Z of FIG. 10A. FIG. 11 is an explanatory view illustrating vertical section taken along line Y-Y of FIG. 10B.

As shown in FIG. 10A, a blade inner-radius-side hollow 3dc and a blade outer-radius-side hollow 3dd of a blade hollow 3d tilt to the inside of the hollow shape with respect to a linear line X parallel with the rotation axis at arbitrary angles θ_1 and θ_2 , respectively, that is, the blade hollow 3d is tapered from the blade opening 3b, as a base, formed in the main plate 2 to the blade suction-side end 3e toward the inside of the hollow shape. Since the blade 3 has almost uniform thickness, the blade inner-radius-side end 3a and the blade outer-radius-side end 3c also

tilt to the inside of the hollow shape, with respect to the linear line X parallel with the rotation axis at the arbitrary angles θ_1 and θ_2 , respectively, that is, the blade ends 3a, 3c are tapered from the blade opening 3b to the blade suction-side end 3e toward the inside of the hollow shape. As shown in FIG. 11, a blade front hollow 3da in the rotation direction D of the blade 3 and a blade rear hollow 3db as a side face in the inverse rotation direction of the blade 3 tilt to the inside of the hollow shape with respect to the linear line X parallel with the rotation axis at arbitrary angles θ_3 and θ_4 , respectively, that is, the side surfaces 3da, 3db of the blade hollow 3d are tapered from the blade opening 3b to the blade suction-side end 3e toward the inside of the hollow shape. Since the blade 3 has almost uniform thickness, the blade inner-radius-side surface 3f and the blade outer-radius-side surface 3g also tilt with respect to the linear line X parallel with the rotation axis, at the arbitrary angles θ_3 and θ_4 , respectively, that is the blade hollow 3d is tapered from the blade opening 3b to the blade suction-side end 3e toward the inside of the hollow shape.

[0049] In short, the blade 3 and the blade hollow 3d have a tapered shape from the main plate 2 to the shroud 4 and tilt to the inside of the hollow at the predetermined angles θ_1 and θ_2 , and the predetermined angles θ_3 and θ_4 . Consequently, at the time of releasing the mold from the fan mold body in the rotation axis direction, the resin and the mold can be smoothly separated from each other because of the tilt. The blade 3 can be prevented from being adhered to the mold and broken, so that moldability can be improved. On completion of cooling and hardening of the resin, the mold is in close contact with the standing faces 3a, 3c, 3f, and 3g of the fan mold body on the outside of the blade 3 having the hollow shape, and further with the standing faces 3dc, 3dd, 3da, and 3db of the fan mold body on the inside or the hollow side of the blade 3. The standing faces on both of the outside and inside of the hollow are tapered from the base in the vertical direction. Consequently, the mold can be easily released on both of the outside of the blade 3 and inside of the hollow of the blade 3.

In addition, the weight of the blade 3 having the hollow shape can be reduced as compared with that of the blade 3 which does not have a hollow shape. In the case where the thickness of the blade 3 is not uniform, poor molding due to variations in cooling and hardening time of the resin occurs, and there is a problem of low moldability. However, the thickness of the blade 3 is made almost uniform, so that the cooling and hardening time of the resin can be made almost uniform, poor molding can be prevented, and moldability can be improved.

[0050] As described above, the turbofan includes: the disc-shaped main plate 2; the projected hub 2a formed by making the center portion of the main plate 2 project in the rotation axis direction; and the plurality of blades 3 each of which has the hollow shape, and is provided so as to stand on the outer-periphery-side flat part of the main plate 2 as a base in the projecting direction of the

hub 2a, the base having the opening 3b. The standing faces 3a, 3g, 3c, and 3f on the outside of the blade 3 having the hollow shape and the standing faces 3da, 3db, 3dc, and 3dd on the inside or the hollow side of the blade 3 tilt to the inside of the hollow, and the outside of the blade 3 and the hollow inside are tapered from the base. With the configuration, the mold can be easily released, and the damage of the blade 3 caused by adhesion of the blade 3 to the mold can be prevented.

Further, by making the thickness of the blade 3 almost uniform, the cooling and hardening time of the resin can be made uniform, and the turbofan having excellent moldability can be obtained.

In addition, by forming the blade 3 in the hollow shape, the whole fan 1 can be made lighter.

[0051] FIG. 12 is a graph showing fan molding time (sec) and noise value (dB) when all of the angle $\theta 1$ of the blade inner-radius-side end 3a with respect to the rotation axis, the angle $\theta 2$ of the blade outer-radius-end 3c with respect to the rotation axis, the tilt angle $\theta 3$ of the blade front hollow 3da with respect to the rotation axis, and the tilt angle $\theta 4$ of the blade rear hollow 3db with respect to the rotation axis are set to the same tilt angle θ , and the tilt angle θ is changed. The axis of abscissa denotes the tilt angle θ and the axis of ordinate indicates the molding time (sec) and the noise value (dB). The noise value (dB) was measured at a point located just below the fan and apart from the fan by 2 m. The molding time is time corresponding to ST2 to ST4 in the flowchart showing the molding process shown in FIG. 7.

[0052] The molding time will be described on the basis of the graph shown in FIG. 12.

In the case where the tilt angle $\theta < 0^\circ$, the blade 3 has a shape widened from the main plate 2 side toward the shroud 4 side, so that the mold cannot be released, and the configuration is impossible. In the case where $\theta = 0^\circ$, that is, in the case where the blade 3 is not tilted with respect to the rotation axis, friction between the blade 3 and the mold is large. If the mold is not released slowly, the blade 3 is broken due to adhesion to the mold, so that long molding time is necessary. In contrast, by employing the tilt angles θ , mold release is facilitated, and mold release time can be shortened. Further, the surface area of the blade 3 increases, and cooling area also increases, so that cooling time is shortened. Consequently, by employing the tilt angles θ , the molding time can be shortened.

When the tilt angle θ is 1° , the molding time becomes about the half of that in the case where the tilt angle θ is 0° . Therefore, when the tilt angle θ is 1° or larger, the molding time is shortened, and moldability is high.

[0053] The noise value will now be described on the basis of the graph shown in FIG. 12.

When the tilt angle θ is too large in the relation between the tilt angle θ and the noise value, the flow path between the neighboring blades 3 and 3 is narrowed, velocity of air passing in the path increases, and it increases noise. According to the result of measurement in FIG. 12, when

the tilt angle θ is larger than 3° , noise increases. Consequently, when the tilt angle θ is set in the range of $1^\circ \leq \theta \leq 3^\circ$, a preferable noise value can be maintained.

As a result, by setting the tilt angle θ in the range of $1^\circ \leq \theta \leq 3^\circ$, the turbofan having small noise change and high moldability is obtained.

[0054] As described above, by making the standing faces 3a, 3g, 3c, and 3f on the outside of the blade 3 having the hollow shape and the standing faces 3da, 3db, 3dc, and 3dd on the inside or the hollow side of the blade tilt to the inside of the hollow, each of the predetermined tilt angles θ is set in the range of $1^\circ \leq \theta \leq 3^\circ$. It produces an effect that the turbofan having small noise change and high moldability is obtained.

[0055] In the above, all of the blade inner-radius-side hollow 3dc, the blade outer-radius-side hollow 3dd, the blade front hollow 3da, and the blade rear hollow 3db of the blade are tilted to the inside of the hollow at the same tilt angle θ with respect to the rotation axis. However, even when they are tilted at angles different from each other, a similar effect is produced.

The blade inner-radius-side end 3a, the blade outer-radius-side end 3c, the blade suction-side end 3e, the blade front side 3f on the front side in the blade rotation direction, and the blade rear side 3g on the rear side in the blade 3 have almost uniform thickness. However, the invention is not limited to the configuration, and they may be slightly different from each other due to molding error and the like. In the blade inner-radius-side end 3a and the blade outer-radius-side end 3c, since the width in the rotation direction is small, and it is difficult to make the thicknesses uniform in this part. It is sufficient to make the thickness of the blade 3 almost uniform with fluctuation to a certain extent. By making the thickness uniform, the resin is injected uniformly and cooled uniformly. Thus, a preferable mold body can be obtained.

[0056] In the embodiment, by making the center portion of the blade 3 upright in the projection direction of the hub 2a from the base of the main plate 2 and tilting the standing faces on the outside of the blade 3 and on the inside or the hollow side to the inside of the hollow, the above effects are obtained. In the configuration, the mold is released in the rotation axis direction and in parallel with the rotation axis. For example, the mold may be also released in the rotation axis direction while slightly turning the mold around the rotation axis as a center. In the case of releasing the mold while rotating it, the configuration in which the center portion of the blade 3 is upright in the projection direction of the hub 2a from the base of the main plate 2 is not employed, but a shape in which the center portion of the blade 3 tilts from the base of the main plate 2 to the blade suction-side end 3e in the rotation release direction by predetermined angle is employed. Also in the case of employing the configuration that the blade 3 tilts, by tilting the standing faces on the outside of the blade 3 and the inside or the hollow side to the inside of the hollow, mold release can be performed easily, and effects similar to the above are pro-

duced.

[0057] The turbofan 1 in which the runners 9 are formed with another configuration will be described. FIG. 13 is a bottom view of the turbofan 1 molded with another runner configuration. In FIG. 13, the same reference numerals as those of FIG. 3 express the same or corresponding parts.

In FIG. 13, runners 9d for cooling holes, each formed so as to surround the motor cooling hole 5 are provided. By connecting the runner 9d and the hub runner 9a, an integral runner is formed.

[0058] In the turbofan constructed as described above, part of the resin injected from the resin injection port 10 at the time of molding flows from the hub runner 9a to the runner 9d for a cooling hole and further flows to the hub 2a and the boss 2c. At this time, the resin flowing in the hub runner 9a is branched to two directions in the cooling hole runner 9d, and flows in the cooling hole runner 9d provided around the motor cooling hole 5. After the resin flows around the motor cooling hole 5, the resin merges again with reliability on the side of the boss 2c of the motor cooling hole 5, and flows toward the boss 2c. As described above, by providing the cooling runner 9d, the flowability of the resin around the motor cooling hole 5 improves, so that moldability can be improved.

By providing the cooling hole runner 9d around the motor cooling hole 5, the resin in the cooling hole runner 9d is hardened to remain around the motor cooling hole 5 as an opening, and the periphery of the motor cooling hole 5 is made thick.

Consequently, the strength around the motor cooling hole 5, which tends to decrease due to the opening, can be improved. Thus, the turbofan having durability against a breakage even with an impact applied is obtained.

[0059] FIG. 14 is a bottom view of the turbofan 1 molded with further another runner configuration. In FIG. 14, the same reference numerals as those of FIG. 3 express the same or corresponding parts.

In FIG. 14, the linear hub runner 9a is connected to the cooling hole runner 9d around the motor cooling hole 5 and is further connected to a hub upper thick portion 2d. The rotation center side of the motor cooling hole 5 is the hub upper thick portion 2d which is thicker than the portion other than the runners in the main plate 2.

[0060] In the turbofan constructed as described above, part of the resin injected from the resin injection port 10 at the time of molding flows from the hub runner 9a to the runner 9d for a cooling hole and further flows to the hub upper thick portion 2d, thereby forming the portion. In a manner similar to the configuration of FIG. 13, the resin flowing in the hub runner 9a is branched to two ways in the cooling hole runner 9d, and flows in the cooling hole runner 9d provided around the motor cooling hole 5. After the resin flows around the motor cooling hole 5, the resin flows to the hub upper thick portion 2d connected to the periphery of the motor cooling hole 5, thereby forming the hub upper thick portion 2d.

[0061] Like the configuration of FIG. 13, by providing

the cooling hole runner 9d around the motor cooling hole 5, the resin in the cooling hole runner 9d is hardened to remain around the motor cooling hole 5 as an opening, and the periphery of the motor cooling hole 5 is made thick. Consequently, the strength around the motor cooling hole 5, which tends to decrease due to the opening, can be improved. By providing the cooling hole runners 9d, moldability and strength can be improved by improvement in the flowability of the resin around the motor cooling hole 5. The turbofan having durability against a breakage even with an impact applied is obtained.

Further, in the configuration, the cooling hole runner 9d is directly connected to the hub upper thick portion 2d around the boss, which is thicker than the hub inclination face.

Consequently, the resin smoothly flows to the hub upper thick portion 2d, and the resin flowing in the cooling hole runner 9d reliably merges again on the front side in the resin flowing direction of the motor cooling hole 5, that is, on the boss 2c side of the motor cooling hole 5, and the merged resin flows to the hub upper thick portion 2d. Therefore, the resin can be reliably injected to the periphery of the motor cooling hole 5 as an opening by an amount of the thickness of the cooling hole runner 9d. Thus, the strength around the motor cooling hole 5, which tends to decrease due to the opening, can be improved.

[0062] As described above, by providing the cooling hole runner 9d connected to the hub runner 9a and formed so as to surround the motor cooling hole 5, the turbofan realizing improved moldability and strength by improvement in the flowability of the resin around the motor cooling hole 5 can be obtained.

[0063] Next, the blade runner 9b will be described in detail. FIG. 15 is a perspective view of the turbofan according to the embodiment and having another configuration, viewed from below.

FIG. 16 is a partly enlarged perspective view showing a part of FIG. 15. FIGS. 17A and 17B and FIGS. 18A and 18B are explanatory views illustrating one blade 3. FIG. 17A is a side view of the blade 3 and FIG. 17B is a transverse section taken along line Z-Z of FIG. 17A. FIG. 18A is a cross section taken along line Y-Y of FIG. 17B. FIG. 18B is an enlarged view of the portion of a circle M in FIG. 18A. FIG. 19 is an explanatory view illustrating a part of the bottom face of the turbofan 1.

[0064] The configuration of the turbofan shown here is another configuration of the blade runner 9b provided around the blade opening 3b formed in the base of the blade 3.

For example, as shown in FIGS. 15 to 18B, the blade runner 9b is provided around the opening in the blade 3 having a hollow shape, and the blade runner 9b on the front side in the blade rotation direction is called a blade front runner 9ba, and the blade runner 9b on the rear side in the blade rotation direction is called a blade rear runner 9bb. The projection height from the face of the main plate 2 of the blade front runner 9ba and that from the face of the main plate 2 of the blade rear runner 9bb

are made different from each other. The projection height in the rotation axis direction of the blade front runner 9ba is set to be larger than that of the blade rear runner 9bb by a predetermined height, and the blade front runner 9ba is made project to the outside of the fan.

[0065] An air current C near the main plate 2 at the blade opening 3b generated at the time when the fan 1 rotates in the direction D collides with the blade front runner 9ba, is curved outward, draws a parabola, and flows so as to approach the main plate 2 again on the blade rear runner 9b side. FIG. 16 is an enlarged view showing this state. If the blade front runner 9ba and the blade rear runner 9bb have the same height, at the time of rotation of the fan, the flow around the main plate 2 is apart from the blade front runner 9ba and collides with the corner of the blade rear runner 9bb, so that pressure fluctuation occurs, causing a problem such that noise occurs in the narrow band.

[0066] In contrast, when the blade front runner 9ba is set to be higher than the blade rear runner 9bb by predetermined height as shown in FIG. 18B, the flow near the blade opening 3b is as shown by the arrow C in FIG. 18A. Specifically, the flow after departing from the blade front runner 9ba draws a parabola which curves to the outside of the main plate 2 and flows so as to approach the main plate 2 again on the rear side in the rotation direction of the blade rear runner 9bb. If the blade front runner 9ba is set to be higher, the air current C curves to the outside from the surface of the main plate 2 so that the departing distance from the main plate 2 increases. As a result, a re-attachment point of the air current C shifts to the rear side of the blade rear opening 3b. By making the air current C smoothly re-attached on the rear side of the blade rear opening 3b, the air current C can be prevented from collision with the corner of the blade rear runner 9bb, and noise can be reduced.

Since the blade front runner 9ba becomes thicker, the resin flows to the blade 3 more smoothly. As a result, shrinkage can be prevented, and moreover, the strength in the blade front runner 9ba improves, so that the strength of the fan also improves.

[0067] As described above, by making the blade front runner 9ba higher than the blade rear runner 9bb by predetermined height so as to project toward the outside of the fan, the light, strong, highly reliable, and low-noise turbofan, which can be prevented from being broken at the time of rotation and transportation, is achieved.

[0068] The difference Δt (shown in FIG. 18B) between the height of the blade front runner 9ba and the height of the blade rear runner 9bb of the blade runner 9b formed' so as to surround the blade 3, with respect to the maximum opening diameter F of the blade opening 3b of the blade having a hollow structure shown in FIG. 19 will be described. The maximum opening width F is the diameter of an inscribing circle of the opening on the face of the main plate 2, and Δt denotes the difference between the height of the blade front runner 9ba and the height of the blade rear runner 9bb.

When the height difference Δt is small, the flow departing from the blade front runner 9ba does not draw a parabola having a sufficient height but collides with the corner of the blade rear runner 9bb. Consequently, noise occurs due to pressure fluctuations in the blade opening 3b. On the contrary, when the blade front runner 9ba is too high, that is, the difference Δt is too large, the flow is separated by the blade front runner 9ba, and a peak sound due to the rotation speed is generated. As described above, a desirable range of the difference Δt between the height of the blade front runner 9ba and the height of the blade rear runner 9bb exists.

[0069] The flow crossing the blade opening 3b relates to not only the difference Δt between the height of the blade front runner 9ba and the blade rear runner 9bb but also the maximum opening diameter F of the blade opening 3b. Consequently, the ratio ($\Delta t/F$) of the difference Δt between the height of the blade front runner 9ba and the height of the blade rear runner 9bb to the maximum opening diameter F of the blade opening 3b is calculated.

FIG. 20 is a graph showing the relation between the ratio ($\Delta t/F$) % and the noise value (dB) with the same air volume. The axis of abscissa denotes the $\Delta t/F$ (%) and the axis of ordinate indicates the noise value (dB). The noise value was measured just below the fan and 2m apart therefrom.

[0070] By constructing the turbofan so that the ratio lies at least in the range of $4\% \leq \Delta t/F \leq 22\%$ on the basis of the measurement result shown in FIG. 20, the turbofan with noise lower than that in the case where the projection height from the face of the main plate 2 of the blade front runner 9ba and that of the blade rear runner 9bb are the same, that is, $\Delta t = 0$ ($\Delta t/F=0$) is obtained.

In the case where $\Delta t/F < 4\%$, the difference Δt of the runners is small with respect to the maximum opening diameter F. Thus, the possibility that the flow departing from the blade front runner 9ba collides with the corner of the blade rear runner 9bb becomes high, and pressure fluctuation occurs so that noise is generated in the narrow band. On the other hand, in the case where $22\% < \Delta t/F$, the difference Δt of the projection heights of the runners is large with respect to the maximum opening diameter F. Thus, the flow departing from the blade front runner 9ba is separated, and noise increases by a peak sound due to the rotational speed.

[0071] As described above, by forming the turbofan so that the difference between the projection height of the blade front runner 9ba and the projection height of the blade rear runner 9bb with respect to the maximum opening diameter F of the blade opening 3b is set in the range of $4\% \leq \Delta t/F \leq 22\%$, the noise can be suppressed, which is generated in the narrow band at the time of rotation of the fan since the flow around the main plate 2 is apart from the blade front runner 9ba, collides with the corner of the blade rear runner 9bb so that pressure fluctuation occurs. A re-attachment point of the air current after departing from the blade front runner 9ba to the rear side in the rotation direction of the blade rear runner 9bb is

moved to the rear side of the blade rear opening 3g, so that the air current C is smoothly re-attached on the rear side of the blade rear opening 3g. Since the projection height of the blade front runner 9ba is not too high, so that the flow is not separated by the blade front runner 9ba, occurrence of generation of a peak sound due to rotation speed is suppressed, and deterioration in noise can be prevented.

Consequently, reduction in noise can be achieved.

[0072] Therefore, by forming the turbofan so that the ratio $\Delta t/F$ of the difference Δt of the projection heights of the blade front runner 9ba and the blade rear runner 9bb to the maximum opening diameter F of the blade opening 3b of the blade having the hollow structure lies in the range of $4\% \leq \Delta t/F \leq 22\%$, noise can be reduced.

[0073] By providing the above-described configuration of the fan in addition to the configurations of the blade opening 3b and the blade runner 9b, further effects can be obtained.

For example, by providing the motor cooling holes 5 so as to avoid the resin merging portions, the turbofan having high reliability in strength is obtained. By providing the hub runner 9a, the resin flows easily to the boss 2c near the top of the main plate 2, and the resin flowability in the whole main plate can be improved. Since the blade 3 has the hollow structure, the weight of the turbofan as a whole can be reduced. Further, the blade hollow 3d has the tapered shape having a molding draft angle, which is tilted at the predetermined angle θ from the main plate 2 toward the shroud 4, so that the mold can be easily released, breakage of the blade due to adhesion of the blade 3 to the mold can be prevented, and moldability is high. Since the thickness of the blade 3 is almost uniform, the cooling and hardening time can be made uniform. Therefore, occurrence of poor molding caused by unevenness due to variations in the cooling and hardening time can be prevented to a certain degree.

[0074] In the embodiment, the fan in which the plurality of blades 3 are constructed by seven blades and, accordingly, seven runners 9 and seven motor cooling holes 5 are provided has been described. However, the number of blades 3, the number of runners 9, and the number of the motor cooling holes 5 are not limited to the above but may be arbitrary.

Although the number of the motor cooling holes 5 is the same as that of the hub runners 9a, as described above, the number of motor cooling holes 5 may be set to be smaller than the number of hub runners 9a. When the motor cooling hole 5 is disposed on the extension line of the hub runner 9a, the motor cooling hole 5 and the resin merging portion do not meet with each other, so that the strength is high. Consequently, even in the case where the number of motor cooling holes 5 is set to be smaller than that of the hub runners 9a, it is preferable to dispose the motor cooling hole 5 on the extension line of the hub runner 9a. By decreasing the number of the motor cooling holes 5, although the function of cooling the motor decreases, the strength of the hub 2a of the fan can be

increased.

[0075] FIGS. 21 to 23 show an example of the configuration in which the turbofan 1 described in the embodiment is mounted on an air conditioner. FIG. 21 is a perspective view showing a state where an air conditioner is mounted in the ceiling, viewed from a room. FIG. 22 is a vertical cross section of the air conditioner. FIG. 23 is a horizontal cross section of the air conditioner. An example of mounting the turbofan 1 in a recessed air conditioner in the ceiling will be described.

[0076] The air conditioner shown in FIG. 21 is a recessed air conditioner in the ceiling and faces a room 19 through a decorative panel 13 having an almost square shape. In a center portion of the decorative panel 13, a suction grille 13a as an air suction port to the air conditioner body, and a filter 20 for removing dust from air passing through the suction grille 13a are disposed. The decorative panel 13 also has panel's blowout ports 13b formed along sides of the decorative panel 13. Each of the panel's blowout ports 13b has a wind direction vane 13c.

[0077] As shown in FIG. 22, an air conditioner body 12 is disposed with a top plate 12c facing up for the room 19, side plates 12d are attached to the sides of the top plate 12c, and is mounted so that the lower side opens to the room 19. A body's suction port 12a in the center portion of the under face of the air conditioner body 12 is disposed so as to communicate with the suction grille 13a of the decorative panel 13. Body's blowout ports 12b are disposed around the body's suction port 12a are disposed so as to communicate with the panel's blowout ports 13b. The air conditioner body 12 has therein the fan 1, a bell mouth 14 forming a suction air path of the turbofan, and a motor 8 for rotating the fan 1.

[0078] A heat exchanger 15 is disposed in a discharge air path extending from a part between the blades as an air current blowing part in the fan 1 to the panel's blowout ports 13b. The heat exchanger 15 has aluminum fins 15a and heat transfer tubes 15b. The heat exchanger 15 has a configuration that the plurality of aluminum fins 15a each having a rectangular shape, which extend in the height direction of the air conditioner body 12, that is, in the vertical direction are stacked at predetermined intervals and the heat transfer tubes 15b in a plurality of stages penetrate the fins in the stack direction.

As shown in FIG. 23, the heat exchanger 15 is formed almost in a C shape so as to surround the periphery side of the turbofan 1. To the heat transfer tubes 15b at one of two ends of the heat exchanger 15 having an almost C shape, a header 16 for adjusting an amount of refrigerant to each of the heat transfer tubes 15b, a distributor 17, and connecting pipes 18 connecting the distributor 17 with the outside unit are attached. A refrigerant such as carbon dioxide is circulated in the heat transfer tubes 15b.

[0079] By the air conditioner constructed as described above, when the turbofan 1 rotates in the rotation direction D, air in the room 19 passes through the suction grille

13a of the decorative panel 13 and the filter 20 and dusts are removed from the air. The resultant air passes through the body's suction port 12a and the bell mouth 14 and is sucked in the turbofan 1. The air passes between the blades 3 of the turbofan 1 and is discharged toward the heat exchanger 15. The indoor air is heat-exchanged with the refrigerant flowing in the heat transfer tubes 15b at the time of passing through the heat exchanger 15, thereby performing heat exchange for heating, cooling, or the like or dehumidification. After that, when the air blows out from the body's blowout port 12b and the panel's blowout ports 13b into the room 19, the direction of the air is controlled by the wind direction vanes 13c.

[0080] At the time of transporting the air conditioner, usually, the air conditioner is held so that the rotation axis direction of the turbofan 1 is perpendicular, that is, the rotary shaft of the fan motor 8 is perpendicular. Specifically, the air conditioner body 12 is loaded onto a truck or the like and carried in a state where the body top plate 12c becomes an under face or the bell mouth 14 side of the air conditioner body 12 becomes the under face.

[0081] By mounting the turbofan 1 according to the embodiment in the recessed air conditioner shown in FIGS. 21 to 23, the following effects are produced. By the improvement in the moldability of the turbofan 1, the turbofan 1 can be made thinner and lighter, and the weight of the whole product can be reduced. Since the strength reliability is improved, the turbofan 1 can be prevented from being damaged by an impact such as vibration at the time of transportation. The product reliability of the air conditioner can be also improved.

In the turbofan 1 in which the motor cooling holes 5 and the blades 3 are disposed at unequal pitches, turbulent flow released from the motor cooling holes 5 to the outside of the turbofan 1 and the flow blowing from the blades 3 do not have periodicity. Therefore, noise due to the rotational speed of the fan can be reduced, and reduction in noise can be achieved. By mounting the fan 1 on the air conditioner, the turbulent flow flowing out from the fan 1 to the panel's blowout port 13b is also reduced. Consequently, noise in the fan 1 is reduced and, in addition, noise in the air conditioner can be further reduced, so that a quiet air conditioner is obtained. Since heat exchange is performed with the refrigerant in the heat exchanger 15 in a state where the turbulent flow is reduced, the efficient air conditioner is obtained.

[0082] The present invention is not limited to the recessed air conditioner shown in FIGS. 21 to 23. Although the air conditioner having the panel's blowout ports 13b in four directions in the ceiling has been described here, two panel's blowout ports 13b may be provided in two directions so as to face each other. The air conditioner may not be entirely mounted in a recess in the ceiling but may be mounted in a state where it is projected downward from the surface of the ceiling. The air conditioner is not limited to a ceiling mounting type but may be a wall mounting type. By applying the turbofan according to the

embodiment to an air conditioner having another configuration on which the turbofan is mounted, in a manner similar to the above, breakage of a fan during product transportation can be prevented, and a quiet and light air conditioner with low noise, high product quality, and high portability is obtained.

[0083] As described above, by the configuration including at least any one of the turbofans described in the embodiment and a heat exchanger, in which air sucked from a suction port by the turbofan is heat-exchanged with a refrigerant in the heat exchanger, and blowing the resultant from a blowout port, a lightweight air conditioner having high reliability in strength and achieving reduced noise is obtained.

The invention is not limited to the air conditioner but can be also applied to a ventilation fan and an air cleaner each including a turbofan, and effects similar to the above can be obtained.

[0084] According to the present invention, the following effects can be obtained.

The plurality of hub runners 9a, which are connected to the resin injection ports 10 and extended linearly in the fan radial direction with a thickness larger than that of the inclined face of the hub 2a of the main plate, are provided in predetermined intervals in the side face on the motor side of the main plate 2. When resin flows from the hub runners 9a to the hub upper thick portion 2d near the boss thicker than the inclined face of the hub at the time of molding, the resin merging portion A is not connected to the motor cooling hole 5 as an opening having low strength against an impact but is formed between the motor cooling holes 5. Consequently, the resin flows easily to the boss 2c to improve moldability, and the resin merging portion formed in the main plate 2 can be made short. Thus, even if an impact is applied in the axial direction (vertical direction in FIG. 1B) of the turbofan 1 at the time of transportation or the like so that a crack occurs in the worst case, the turbofan is resistant to breakage. The improved moldability and high reliability against an impact of the turbofan can be achieved.

[0085] The motor cooling holes 5 are disposed near the fan center-side ends 9a1 of the hub runners 9a, and at least the number of the motor cooling holes 5 and the number of the hub runners 9a are the same. Further, the blade inner-radius-side ends 3a are disposed near the fan outer-radius-side ends 9a2 of the hub runners 9a. The hub runners 9a and the blade runners 9b formed so as to surround the openings 3b of the blades 3 are connected to each other via the connection runners 9c, so that the resin merging portion A made of the resin flowing from the hub runners 9a is formed between the motor cooling holes 5 with reliability. As a result, even if an impact is applied in the axial direction (vertical direction in FIG. 1B) of the turbofan 1 at the time of transportation or the like so that a crack occurs in the worst case, the turbofan is resistant to breakage. The improved moldability and high reliability against an impact of the turbofan can be achieved. Since the hub runner 9a and the blade

runner 9b are not integrally formed, the amount of injection of the resin injected from the resin injection port 10 between the hub runner 9a and the blade runner 9b can be adjusted.

Therefore, occurrence of cavity and locally small thickness due to uneven flow can be prevented, and thereby deterioration in strength can be prevented. Since the resin flows more easily because of the blade runners 9b, the thickness of the blade 3 can be reduced, and the thickness of the connection part of the blade 3 and the main plate 2 on which stress is concentrated can be increased. Thus, both improvement in moldability and improvement in strength of the turbopan can be realized by improvement in the resin flowability.

[0086] Since the neighboring linear hub runners 9a are formed so as not to overlap each other, the main current direction of the resin is the radial direction so that the flow direction is less complicated as compared with the conventional case where ribs forming runners to one resin injection port 10 are numerous, the resin merging portion A can be made clearer, the number of resin merging portions A can be reduced, the mold design can be simplified, occurrence of cavity and locally small thickness due to uneven flow can be prevented, and deterioration in strength of the turbopan can be prevented.

[0087] Since the hub runner 9a is projected to the fan external air duct 7 side of the main plate, the hub runner 9a can also serve as an air guide for inducing flow G toward the motor cooling hole 5. With the configuration, air flowing on the surface of the fan motor 8, which is mounted on the side of the fan external air duct 7 of the hub 2a and fixed to the turbopan 1 by the boss 2c, increases, so as to cool the motor more easily. Therefore, the temperature protection control for coping with the motor temperature rise is made unnecessary and, further, breakage of the motor due to high temperature can be also prevented.

[0088] The resin injection port provided near the blade inner-radius-side end and the blade runner formed so as to surround the main-plate-side opening of the blade having the hollow shape are connected to each other via the connection runner. The blade inner-radius-side hollow, the blade outer-radius-side hollow, the blade front hollow surface, and the blade rear hollow surface of the blade hollow are faces tilted at an arbitrary angle θ with respect to the rotation axis. The blade inner-radius-side end, the blade outer-radius-side end, the blade suction-side end, and the blade front-side end on the front side and the blade rear-side end on the rear side in the blade rotation direction are formed so as to have almost the same thickness in the entire blade. The blade and the blade hollow are formed so as to be tapered from the main plate toward the shroud. Since the blade has a hollow structure, the weight of the blade can be reduced. Because of almost uniform thickness, occurrence of poor molding caused by variations in the cooling and hardening time of the resin due to non-uniform blade thickness is suppressed, so that moldability is high. In addition, since each of the

blade and the blade hollow has a tapered shape at a molding draft angle, which is tilted at the predetermined angle from the main plate toward the shroud, the mold can be easily released, breakage of the blade due to adhesion of the blade to the mold can be prevented, and moldability is high.

[0089] In a turbopan made of a thermoplastic resin including: a disc-shaped main plate having a projected hub formed by making a center portion so as to cover a motor, a plurality of motor cooling holes formed in the hub, for communicating the motor and the inside of the fan, and a boss as a fixing part to a rotary shaft of a motor, which is provided in the center portion of the hub; a plurality of blades; and a shroud for coupling the plurality of blades to form an air intake wall, a plurality of hub runners each of which is connected to a resin injection port formed in a main plate flat portion near the blade inner-radius-side end, made thicker than the inclined face of the main plate, and extended linearly in the radial direction of the fan, is provided in predetermined intervals on the motor-side side face of the main plate. The hub runners are so formed that a resin merging portion formed between neighboring hub runners is not connected at least to the motor cooling holes. The blade inner-radius-side hollow, the blade outer-radius-side hollow, the blade front hollow surface, and the blade rear hollow surface of the blade hollow are faces tilted at an arbitrary angle θ with respect to the rotation axis. The blade inner-radius-side end, the blade outer-radius-side end, the blade suction-side end, and the blade front-side end on the front side and the blade rear-side end on the rear side in the blade rotation direction are formed so as to have almost the same thickness in the entire blade. The blade and the blade hollow are formed so as to be tapered from the main plate toward the shroud. Because of the hub runners, resin flowability in the hub and the main plate is high, and moldability is high. Since the hub runners are formed so that the resin merging portion does not communicate with at least the motor cooling holes, breakage of the fan due to an impact at the time of transportation or the like is prevented. Since the blade has a hollow structure, the weight of the turbopan as a whole can be reduced. Because of almost uniform thickness, occurrence of poor molding caused by variations in the cooling and hardening time of the resin due to non-uniform blade thickness is suppressed, so that moldability is high. In addition, since each of the blade and the blade hollow has a tapered shape at a molding draft angle, which is tilted at the predetermined angle from the main plate toward the shroud, the mold can be easily released, breakage of the blade due to adhesion of the blade to the mold can be prevented, and moldability is high.

Further, because of reduction in the weight of the blades, the weight of the outer peripheral portion of the turbopan relative to the rotation center of the turbopan is reduced. Consequently, centrifugal force at the time of rotation is lessened, the stress applied on the root of the blade on the main plate is reduced, and strength can be improved.

Thus, breakage of the turbofan at the time of rotation can be prevented. As a result, the lightweight and high-reliability turbofan having high moldability and strength is obtained.

[0090] The blade inner-radius-side hollow, the blade outer-radius-side hollow, the blade front hollow surface, and the blade rear hollow surface of the blade hollow are faces tilted at a tilt angle θ of 1° to 3° with respect to the rotation axis. The blade inner-radius-side end, the blade outer-radius-side end, the blade suction-side end, and the blade front-side end on the front side and the blade rear-side end on the rear side in the blade rotation direction are formed so as to have almost the same thickness in the entire blade. The blade and the blade hollow are formed so as to be tapered from the main plate toward the shroud. Since the blade has a hollow structure, the weight can be reduced. Because of almost uniform thickness, occurrence of poor molding caused by variations in the cooling and hardening time of the resin due to non-uniform blade thickness is suppressed, so that moldability is high. In addition, since each of the blade and the blade hollow has a tapered shape at a molding draft angle, which is tilted at the predetermined angle from the main plate toward the shroud, the mold can be easily released, breakage of the blade due to adhesion of the blade to the mold can be prevented, and moldability is high. A noise change is at least small and does not deteriorate. As a result, when at least the tilt angle θ is 1° to 3° , a turbofan with a small noise change and high moldability is obtained.

[0091] The mounting pitch angles σ in the circumferential direction of the blades 3 are set as unequal pitch angles and, simultaneously, the pitch angles γ in the circumferential direction of the motor cooling holes 5 are unequal pitch angles in correspondence with the blades 3. The hub runners 9a extending linearly in the radial direction from the fan rotation center O are also arranged at unequal pitches in correspondence with the blades 3 and the motor cooling holes 5. One resin injection port 10, the hub runner 9a, the blade runner 9b, and the motor cooling hole 5 are disposed almost by the same arrangement. Consequently, molding conditions hardly-change, occurrence of cavity and locally small thickness due to uneven flow can be prevented, and deterioration in strength of the turbofan can be prevented. Since the motor cooling holes 5 and the blades 3 are disposed by the same arrangement, the turbulent flow E2 from the fan outer air duct 7 to the fan inner air duct 6 via the motor cooling hole 5 does not directly collide with the blade 3, the turbofan is not largely subjected to pressure fluctuations so that noise can be reduced.

[0092] The resin flowing out from the resin injection port 10 flows from the hub runner 9a toward the cooling hole runner 9d and flows to the boss 2c. Since there is the cooling hole runner 9d around the motor cooling hole 5, after the resin flows in, the resin is merged again on the rear side in the resin flowing direction of the motor cooling hole, and the merged resin flows to the boss 2c.

Consequently, unlike the conventional technique in which there is no cooling hole runner around the cooling hole and the resin is not easily re-merged on the rear side in the resin flowing direction of the cooling hole, the strength around the motor cooling hole 5, which tends to decrease due to the opening, can be improved. As a result, improvement in both moldability and strength is realized by improvement in the resin flowability around the motor cooling hole, and the turbofan, which is resistive to breakage even when an impact, is applied, is obtained.

[0093] When the ratio $t1/t2$ is in the range of 1.1 to 2, and the ratio $t2/t0$ is in the range of 1.1 to 2 where $t1$ denotes the maximum thickness of the hub runner 9a, $t2$ denotes the maximum thickness of the blade runner 9b, and $t0$ denotes the minimum thickness of the other portion of the main plate 2, molding time can be shortened as compared with the case where the thicknesses are the same ($t1/t0, t2/t0=$). The production amount can be increased in the same time, electricity required for a molding machine can be also reduced, and energy can be saved.

[0094] The blade front runner corresponding to the side face in the blade rotation direction of the blade runner formed so as to surround the opening on the outer side of the main plate of the blade having a hollow structure has a height larger than the blade rear runner corresponding to the side face on the opposite side in the blade rotation direction and is formed so as to project to the outside of the fan. Consequently, the noise can be suppressed, which is generated in the narrow band at the time of rotation since the flow around the main plate is apart from the blade front runner, collides with the corner of the blade rear runner, so that pressure fluctuation occurs. A re-attachment point of the air flow after departing from the blade front runner to the rear side in the rotation direction of the blade rear runner is moved to the rear side of the blade opening so that the air current is smoothly re-attached. Thus, noise can be reduced.

[0095] In a turbofan made of a thermoplastic resin including: a disc-shaped main plate having a projected hub formed by making a center portion so as to cover a motor, a plurality of motor cooling holes formed in the hub for communicating the motor and the inside of the fan, and a boss as a fixing part fixed to a rotary shaft of a motor, which is provided in the center portion of the hub; a plurality of blades; and a shroud for coupling the plurality of blades to form an air intake wall, a plurality of hub runners each of which is connected to a resin injection port formed in a main plate flat portion near the blade inner-radius-side end, made thicker than the inclined face of the main plate, and extended linearly in the radial direction of the fan, is provided in predetermined intervals on the motor-side side face of the main plate. The hub runners are so formed that a resin merging portion formed between neighboring hub runners is not connected at least to the motor cooling holes. The blade inner-radius-side hollow, the blade outer-radius-side hollow, the blade front hollow surface, and the blade rear hollow surface of the blade

hollow are faces tilted at an arbitrary angle θ with respect to the rotation axis. The blade inner-radius-side end, the blade outer-radius-side end, the blade suction-side end, and the blade front-side end on the front side and the blade rear-side end on the rear side in the blade rotation direction are formed so as to have almost the same thickness in the entire blade. The blade and the blade hollow are formed so as to be tapered from the main plate toward the shroud. The blade runner formed so as to surround the opening on the outside of the main plate of the blade having the hollow structure is connected via the connection runner. The blade front runner corresponding to the side face in the blade rotation direction of the blade runner has a height larger than that of the blade rear runner corresponding to the side face on the opposite side in the blade rotation direction and is formed so as to project to the outside of the fan. Because of the hub runners, resin flowability in the hub and the main plate is high, and moldability is high. Since the hub runners are formed so that the resin merging portion is not connected to at least the motor cooling holes, breakage of the fan due to an impact at the time of transportation or the like is prevented. Since the blade has a hollow structure, the weight of the turbofan as a whole can be reduced. Because of almost uniform thickness, occurrence of poor molding caused by variations in the cooling and hardening time of the resin due to non-uniform blade thickness is suppressed, so that moldability is high. In addition, since each of the blade and the blade hollow has a tapered shape at a molding draft angle, which is tilted at the predetermined angle from the main plate toward the shroud, the mold can be easily released, breakage of the blade due to adhesion of the blade to the mold can be prevented, and moldability is high. The noise can be suppressed, which is generated in the narrow band at the time of rotation, since the flow around the main plate is apart from the blade front runner, collides with the corner of the blade rear runner, so that pressure fluctuation occurs. A re-attachment point of the air flow after departing from the blade front runner to the rear side in the rotation direction of the blade rear runner is moved to the rear side of the blade opening so that the air current is smoothly re-attached. Thus, noise can be reduced. Since the blade front runner becomes thicker, the resin flows to the blade more smoothly at the time of molding, and shrinkage can be prevented. Moreover, the strength in the blade front runner improves, so that the strength of the turbofan also improves. As a result, a lightweight, strong, and low-noise turbofan which can be prevented from being broken at the time of rotation and transportation can be obtained.

[0096] The turbofan is formed so that the ratio $\Delta t/F$ of the difference Δt between the height of the blade front runner 9ba and the height of the blade rear runner 9bb with respect to the maximum opening diameter F of the blade opening 3b lies in the range of 4% to 22%. At the time of rotation, the noise can be suppressed, which is generated in the narrow band since the flow around the main plate is apart from the blade front runner, collides

with the corner of the blade rear runner so that pressure fluctuation occurs. A re-attachment point of the air flow after departing from the blade front runner to the rear side in the rotation direction of the blade rear runner is moved to the rear side of the blade opening, so that the air current is smoothly re-attached on the rear side of the blade rear opening, so that noise can be reduced. A peak sound due to rotation speed, which is generated by separating the flow at the blade front runner with a too large thickness, is suppressed, and deterioration in noise can be prevented. Consequently, reduction in noise can be achieved.

[0097] An air conditioner including: the turbofan 1 having any one of the configurations described in the first embodiment; and the heat exchanger disposed on the suction side or the blowout side of the turbofan can be thinned because of improvement in the moldability of the turbofan 1 and, accordingly, the weight can be reduced. In addition, the air conditioner has high reliability in strength. Consequently, at the time of mounting after transportation, the turbofan 1 is not found broken due to an impact such as vibrations at the time of transportation, so that the product reliability is high. The product weight can be also reduced only by the reduced weight of the turbofan 1.

[0098] The present invention also provides an air conditioner recessed in a ceiling, having the following configuration. Side plates and the top plate of the air conditioner body are formed by plate members. The inside of the air conditioner body including the side plates and at least a part of the ceiling serves as an air path wall using heat insulating material. A motor and the turbofan 1 having at least one of the configurations described in the first embodiment are mounted around the center of the air conditioner body. A bell mouth constituting a suction port of the turbofan and a suction port of the body is disposed in the center portion of the under face of the air conditioner body. A heat exchanger is vertically arranged so as to surround the turbofan. A drain pan made of foam is disposed under the heat exchanger. A body's blowout port is provided in a position around the body's suction port and almost along the side plate of the air conditioner body. A decorative panel having a panel's suction port and a panel's blowout port communicating with the body's suction port and the body's blowout port, respectively, is attached to the under face of the body. With the configuration, the air conditioner can be thinned because of improvement in the moldability of the turbofan 1 and, accordingly, the weight can be reduced. In addition, the air conditioner has high reliability in strength. Consequently, at the time of mounting after transportation, the turbofan 1 is not found broken due to an impact such as vibrations at the time of transportation, so that the product reliability is high. The product weight can be also reduced only by the reduced weight of the turbofan 1.

Claims**1.** A turbofan comprising:

a disc-shaped main plate;
 a projected hub formed by making a center portion of the main plate project in a rotation axis direction;
 a plurality of blades each of which is vertically provided in the projecting direction of the hub using an outer-periphery-side flat part of the main plate as a base;
 a plurality of motor cooling holes which are formed in the hub so as to cool a motor disposed in a space having a projection shape surrounded by the hub;
 a plurality of hub runners which are provided radially in the hub and into which a thermoplastic resin is made to flow at the time of molding, so as to form the hub; and
 resin merging portions each of which is formed by merging thermoplastic resin flowing out from the neighboring hub runners at the time of molding,
 wherein the motor cooling holes are disposed so as to avoid the resin merging portions.

2. The turbofan according to claim 1, wherein each of the blades has a hollow shape having an opening in the base, the turbofan includes blade runners which are provided around the bases of the blades so as to form the blades, and connection runners each of which connects one of the hub runners to one of the blade runners positioned close to the hub runner, and the thermoplastic resin is injected from injection ports formed in the hub runners, the connection runners, or the blade runners and allowed to flow into all of the runners, thereby performing molding.

3. A turbofan comprising:

a disc-shaped main plate;
 a projected hub formed by making a center portion of the main plate project in a rotation axis direction;
 a plurality of blades each of which is vertically provided in the projecting direction of the hub using an outer-periphery-side flat part of the main plate as a base, and has a hollow shape with an opening in the base;
 a plurality of hub runners which are provided radially in the hub and to which a thermoplastic resin flows at the time of molding, so as to form the hub;
 a plurality of blade runners which are provided around the bases of the blades and to which thermoplastic resin is allowed to flow at the time

of molding, so as to form the blades; and connection runners each of which connects one of the hub runners to one of the blade runners positioned close to the hub runner.

4. The turbofan according to claim 1, 2, or 3, wherein the plurality of motor cooling holes formed in the hub are disposed in parts on extension lines of the hub runners to the rotation center side.

5. The turbofan according to claim 4, wherein equal numbers of the motor cooling holes and the hub runners are provided.

6. The turbofan according to any one of claims 1 to 5, wherein the hub runners are projected from the face of the main plate of the hub to the motor disposing side.

7. The turbofan according to any one of claims 2, 4 to 6, wherein a plurality of sets each made of the blade, the blade runner, the hub runner, the connection runner, and the motor cooling hole are provided radially around the rotation axis as a center.

8. The turbofan according to claim 7, wherein at least one of angles each formed between neighboring sets is different from the other angles.

9. The turbofan according to any one of claims 1, 2, 4 to 8, further comprising runners for the cooling holes respectively connected to the hub runners and formed so as to surround the motor cooling holes.

10. The turbofan according to any one of claims 2 to 9, wherein when at least either of thickness of the hub runners or thickness of the blade runners is set as "t" and the minimum thickness of a portion other than the runners in the main plate is set as t₀, the ratio t/t₀ is set in the range of $1.1 \leq t/t_0 \leq 2$.

11. A turbofan comprising:

a disc-shaped main plate;
 a projected hub formed by making a center portion of the main plate project in a rotation axis direction;
 a plurality of blades each of which is vertically provided in the projecting direction of the hub using an outer-periphery-side flat part of the main plate as a base, and has a hollow shape with an opening in the base; and
 blade runners each of which is provided around the opening so as to project from the main plate in the direction opposite to the vertically provided direction of the blade,
 wherein projection height of the blade runner positioned in the front part in the rotation direction

of the periphery of the opening is larger than projection height of the blade runner positioned in the rear part in the rotation direction of the periphery of the opening.

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12. The turbofan according to claim 11, wherein when the diameter of an inscribing circle of the opening on the face of the main plate is set as maximum opening width F, and the difference between the projection height of the blade runner positioned in the front part in the rotation direction of the periphery of the opening and the projection height of the blade runner positioned in the rear part in the rotation direction of the periphery of the opening is set as Δt , $\Delta t/F$ is set in a range of $0.04 \leq \Delta t/F \leq 0.22$.

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13. A turbofan comprising:

a disc-shaped main plate; 20
 a projected hub formed by making a center portion of the main plate project in a rotation axis direction; and
 a plurality of blades each of which is vertically provided so as to stand in the projecting direction of the hub using an outer-periphery-side flat part of the main plate as a base, and has a hollow shape with an opening in the base, 25
 wherein standing faces on the outside of the blade having the hollow shape and the inside of the hollow tilt to the inside of the hollow, and the outside of the blade and the hollow inside are tapered from the base. 30

14. The turbofan according to claim 13, wherein the thickness of the blade is almost uniform. 35

15. The turbofan according to claim 13 or 14, wherein the standing faces on the outside of the blade having the hollow shape and the inside of the hollow are tilted to the inside of the hollow at predetermined tilt angles θ with respect to the rotation axis, and each of the predetermined tilt angles θ lies in the range of $1^\circ \leq \theta \leq 3^\circ$. 40

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16. An air conditioner comprising:

the turbofan according to any one of claims 1 to 15; and
 a heat exchanger, 50
 wherein air sucked from a suction port by the turbofan is heat-exchanged with a refrigerant in the heat exchanger, and the resultant air is allowed to blow out from a blowout port. 55

FIG. 1

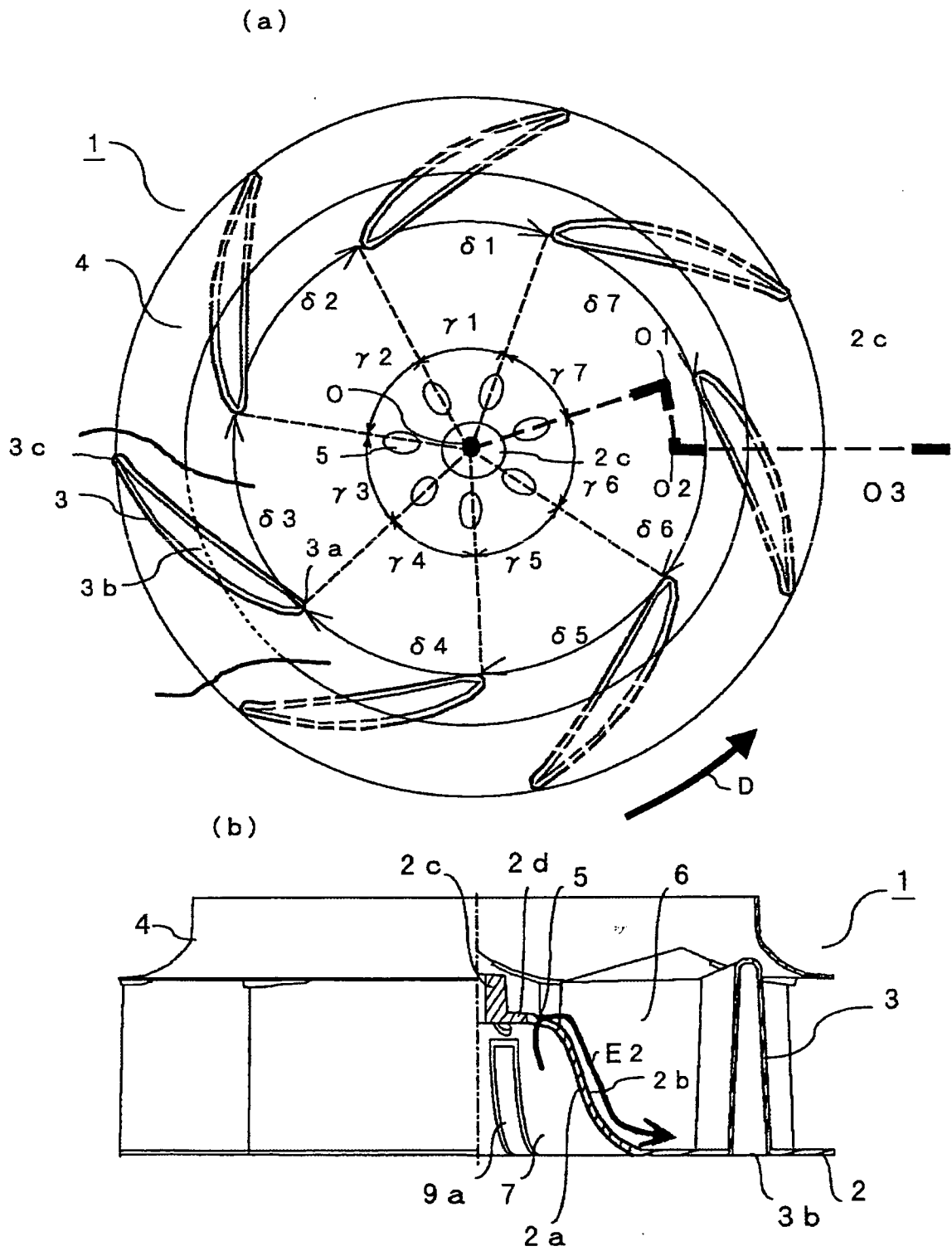


FIG. 2

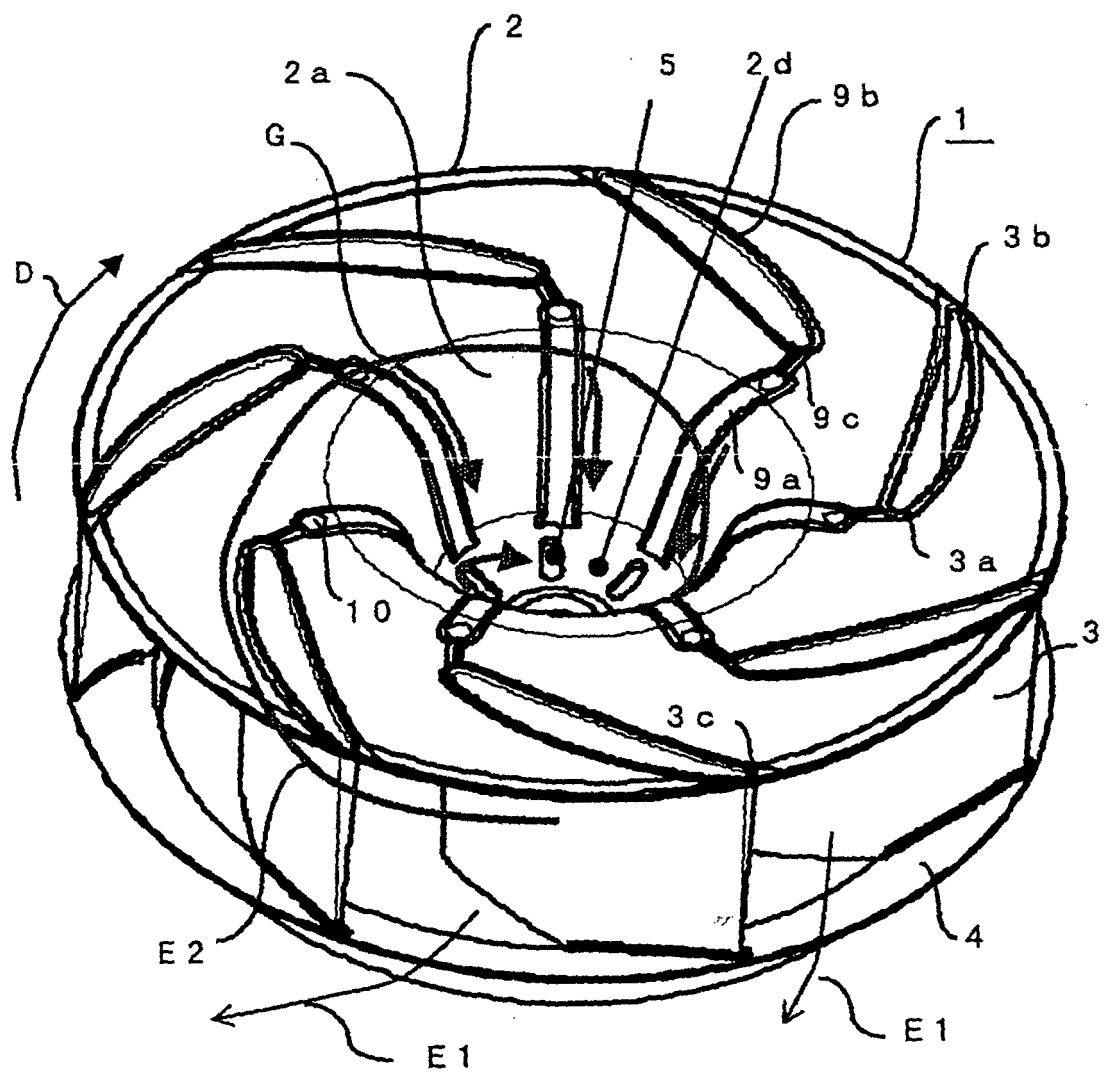


FIG. 3

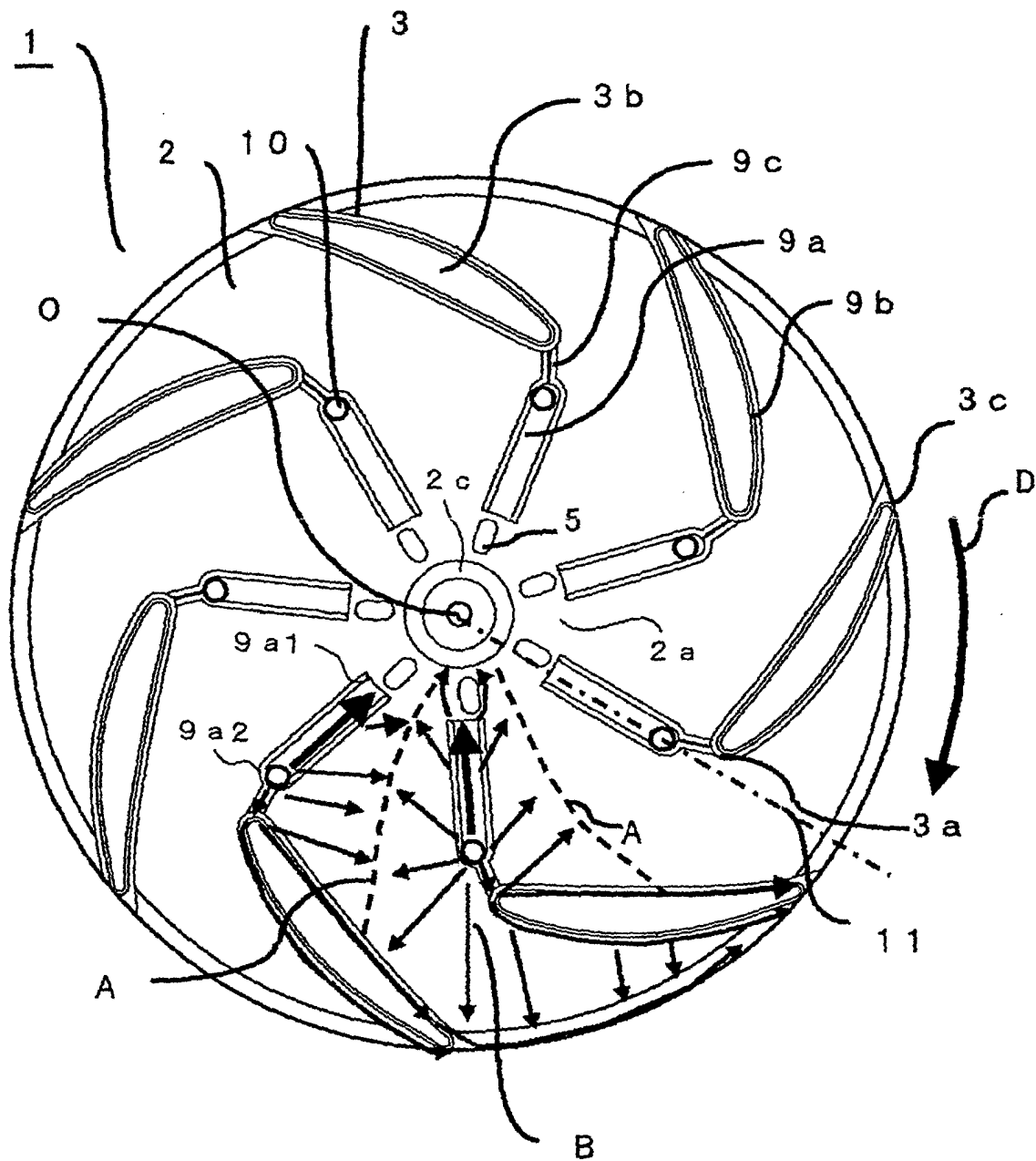


FIG. 4

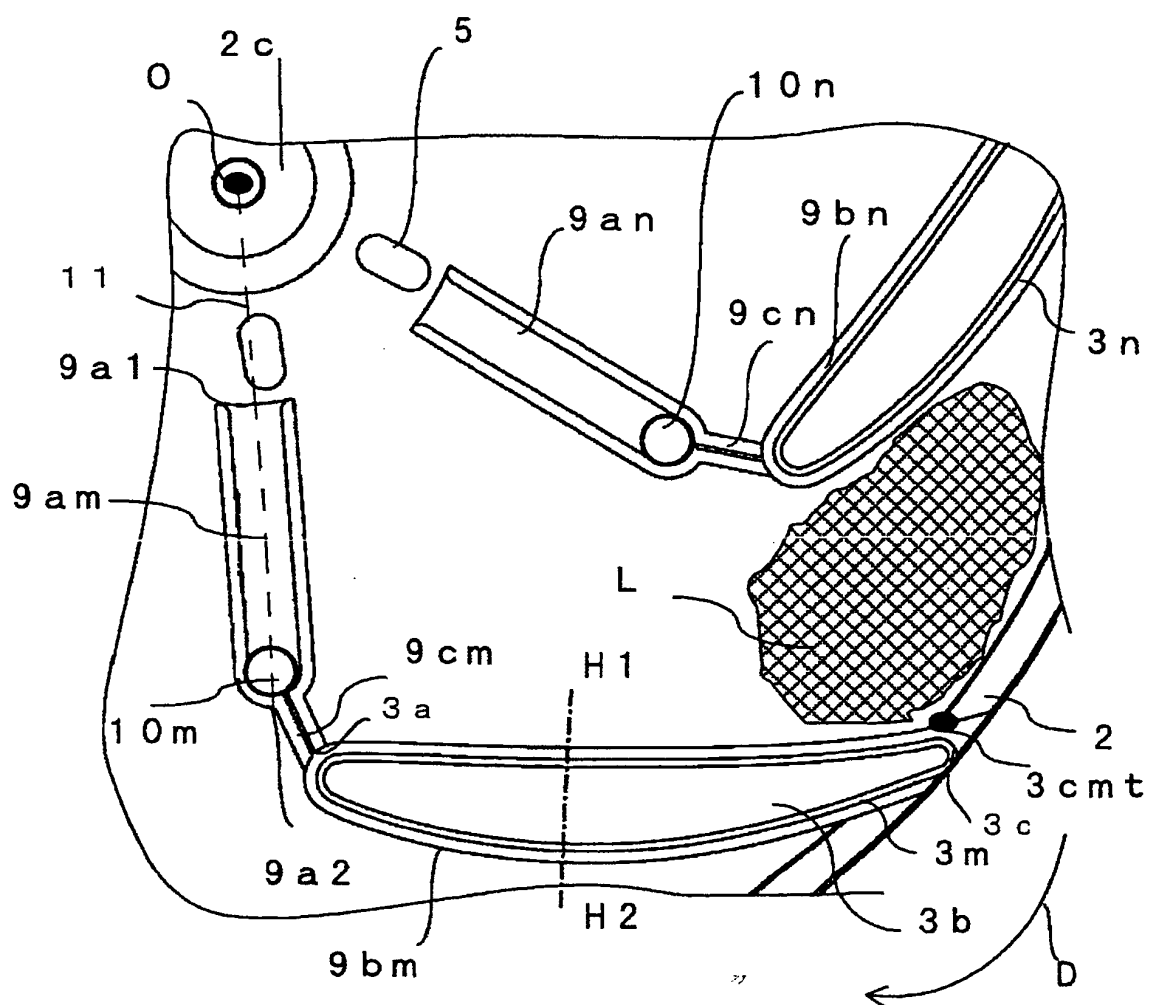


FIG. 5

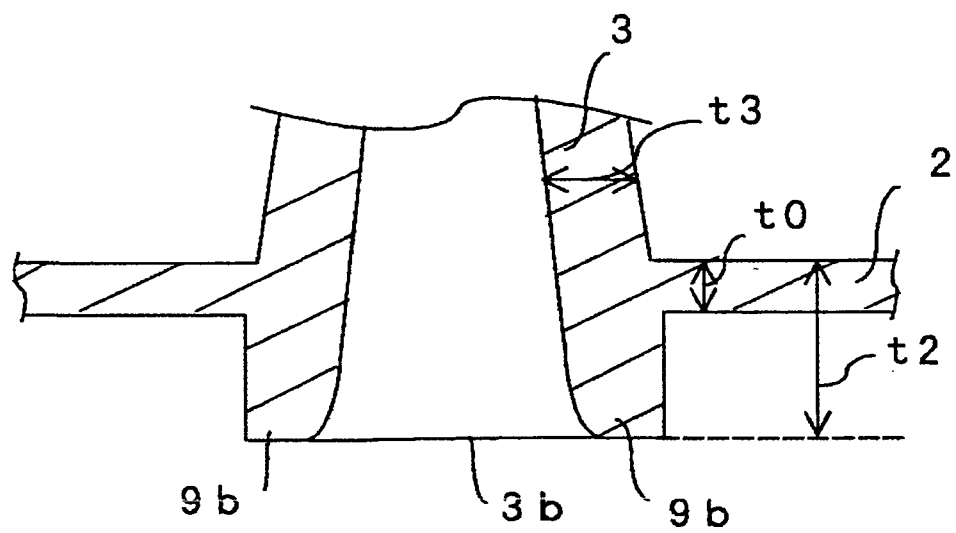


FIG. 6

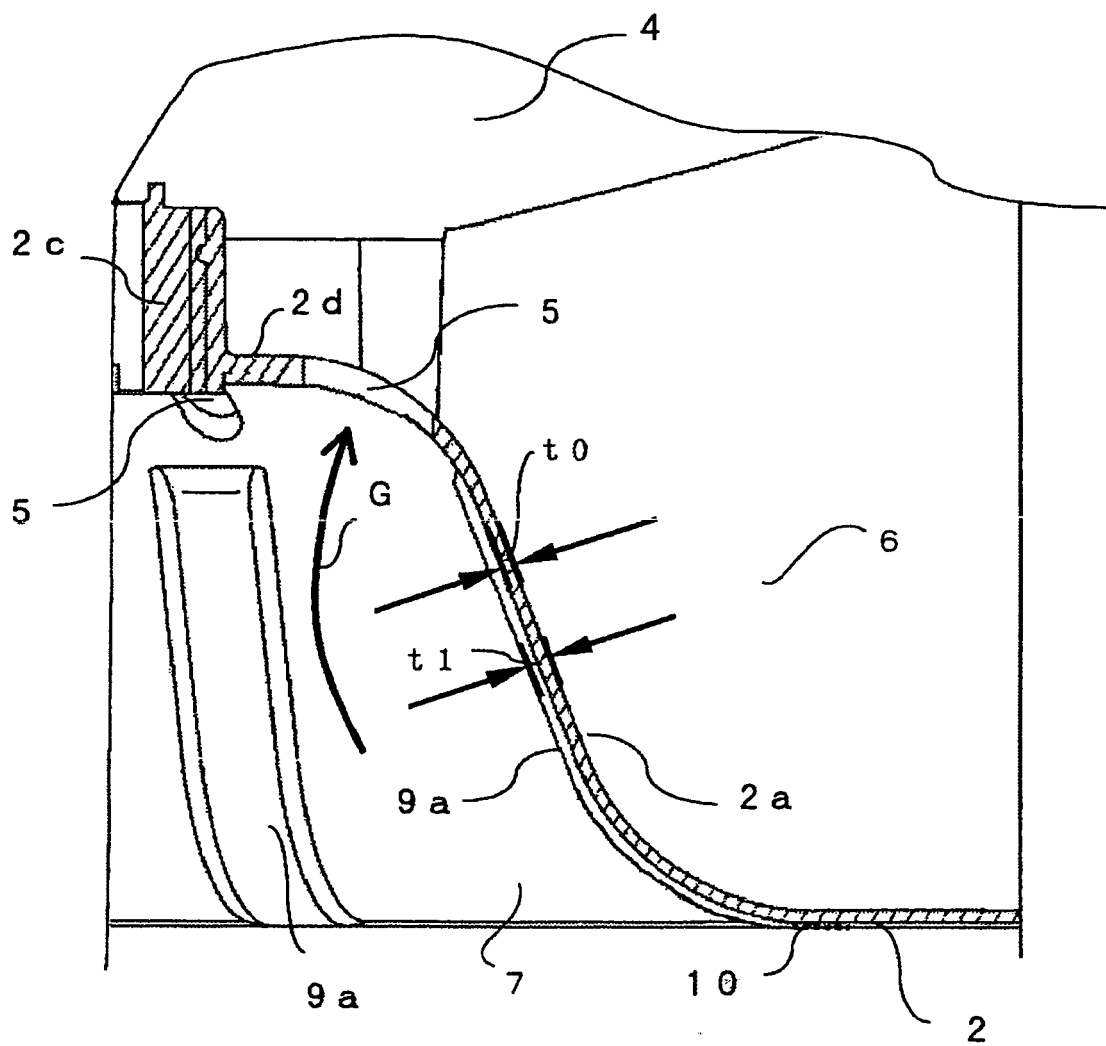


FIG. 7

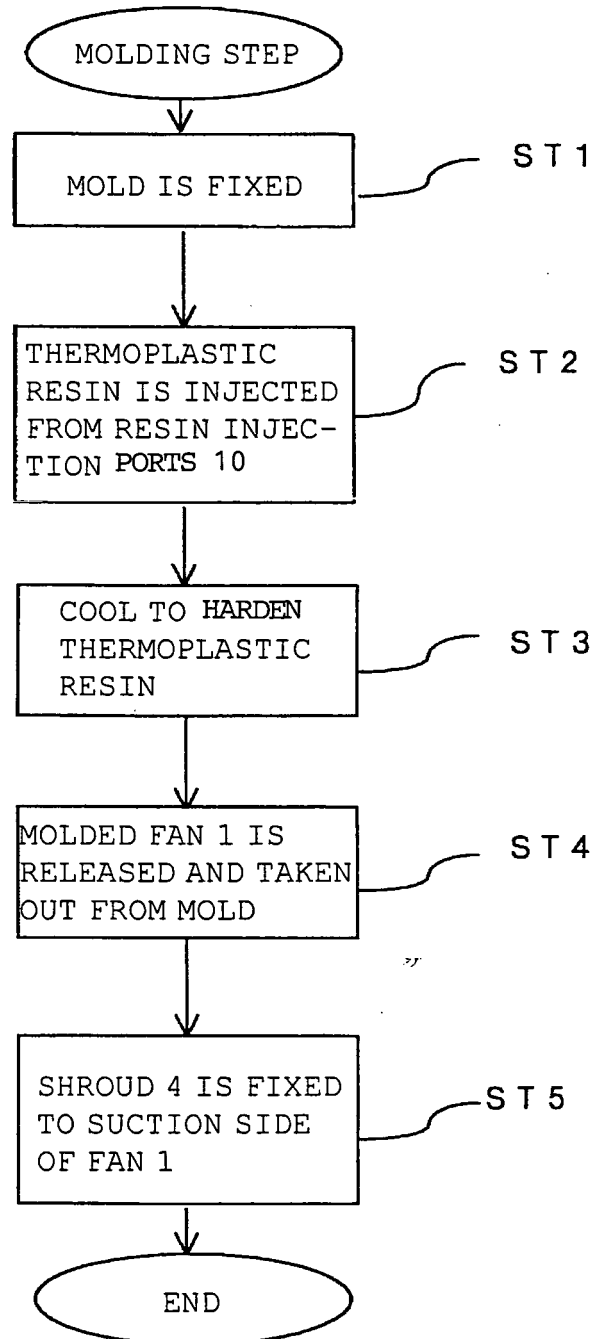


FIG. 8

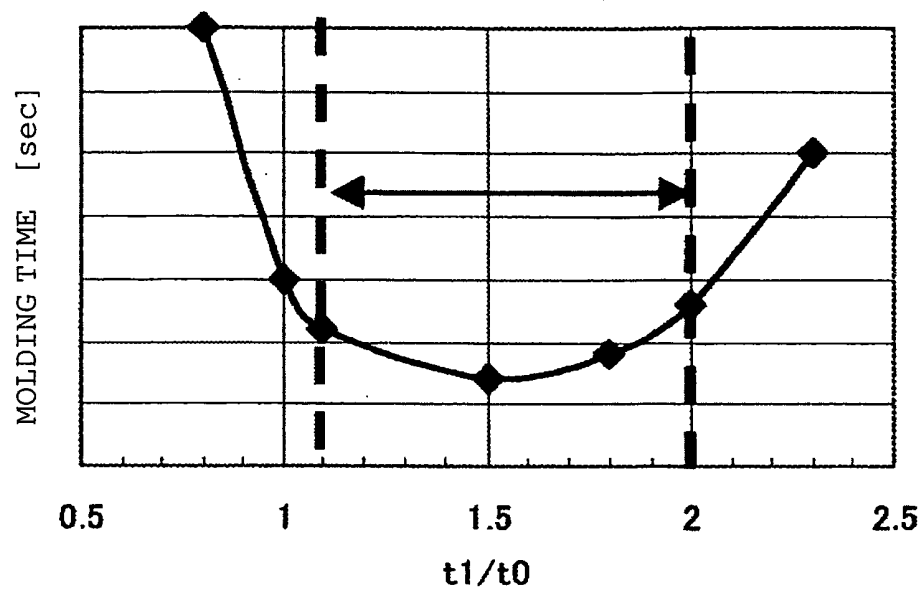


FIG. 9

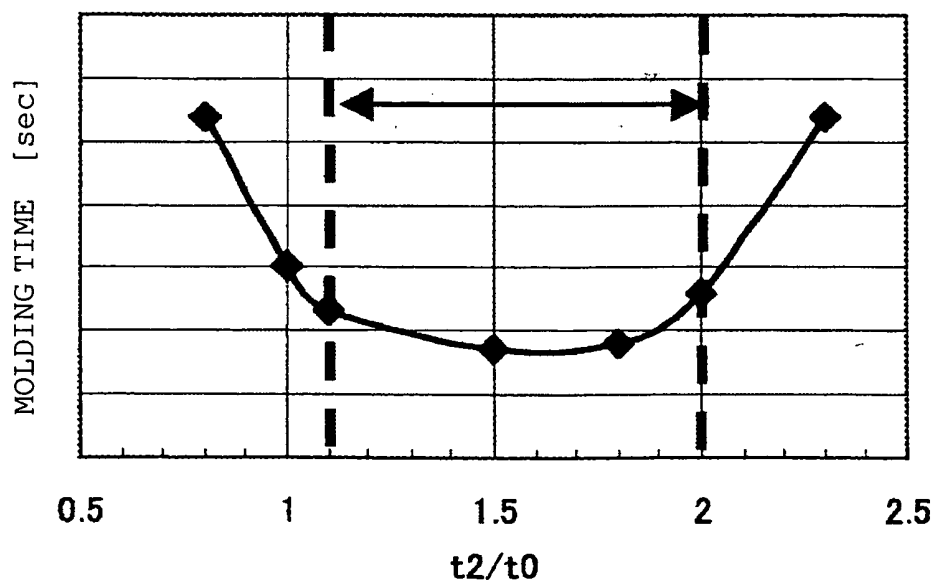


FIG. 10

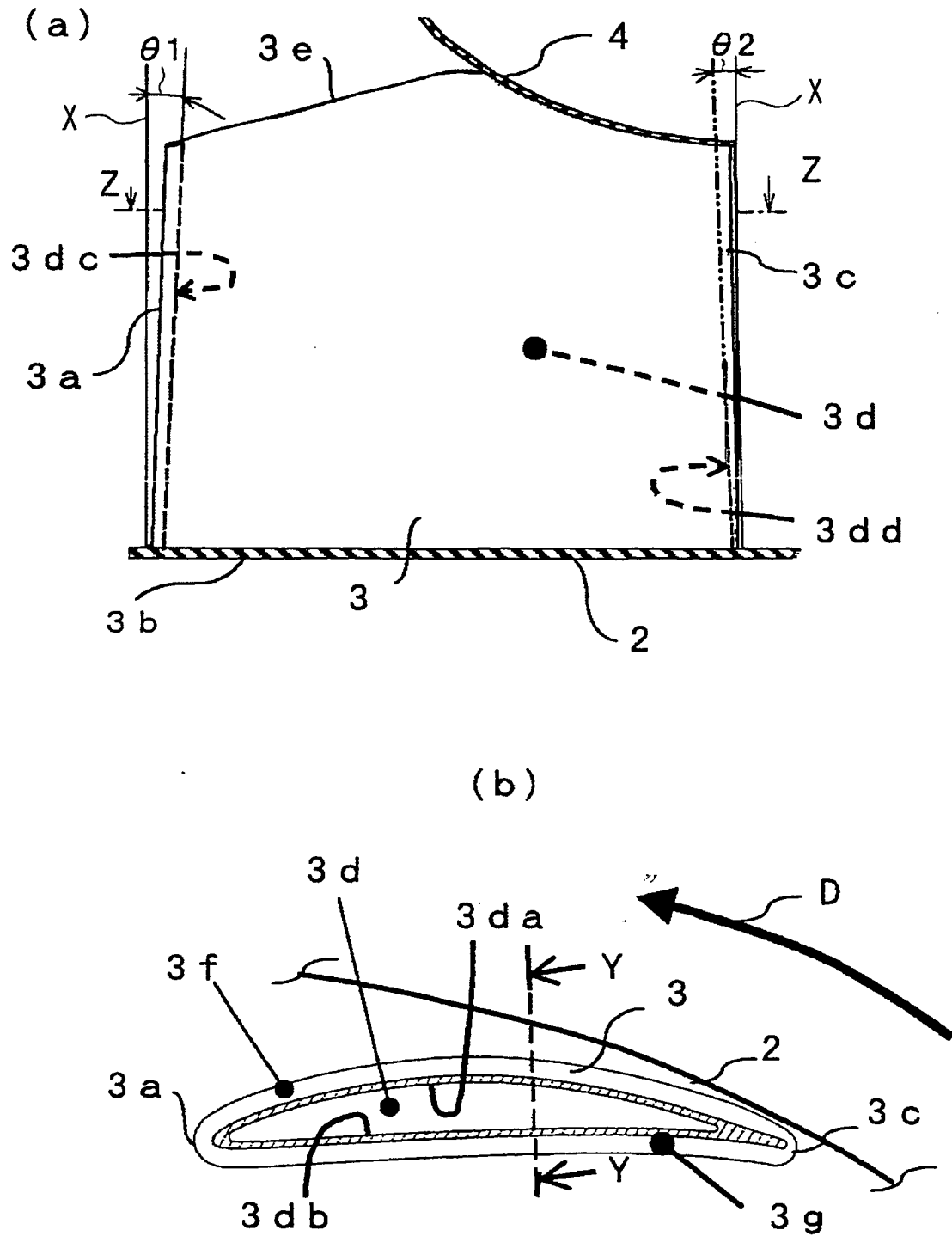


FIG. 11

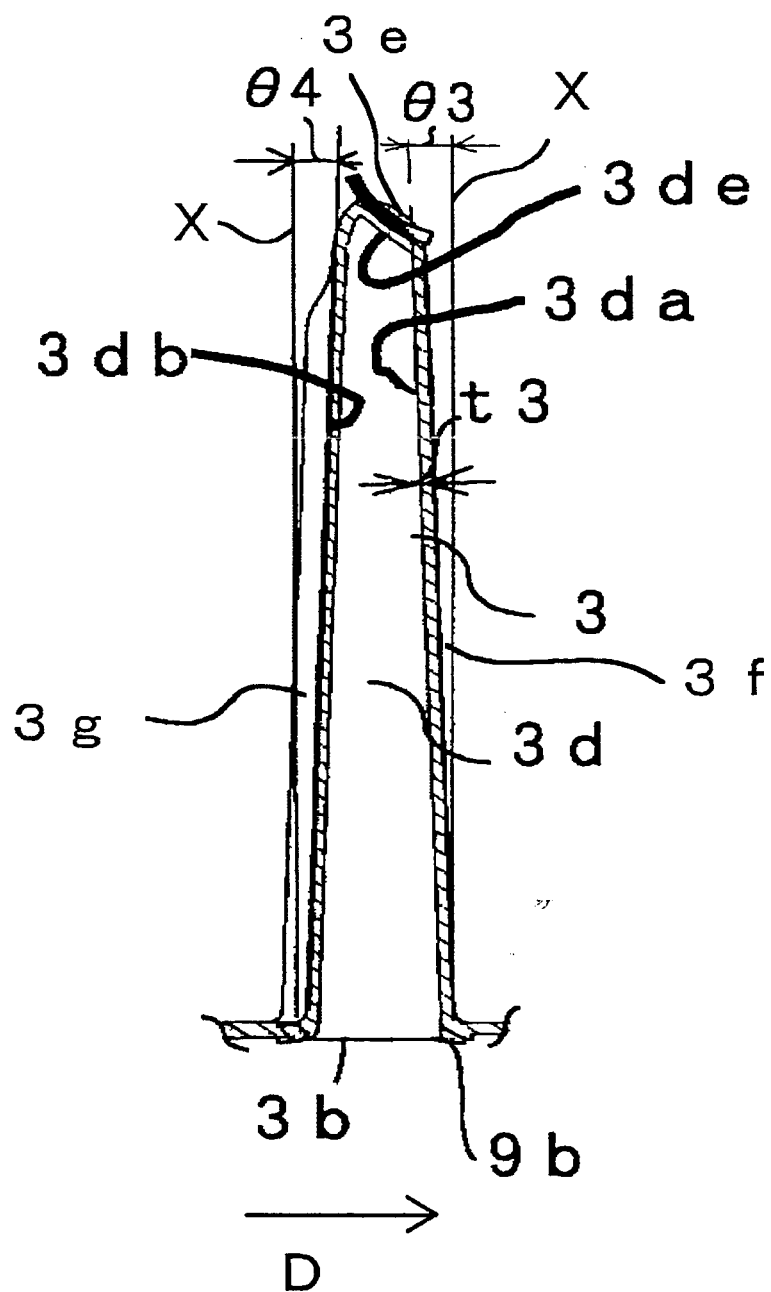


FIG. 12

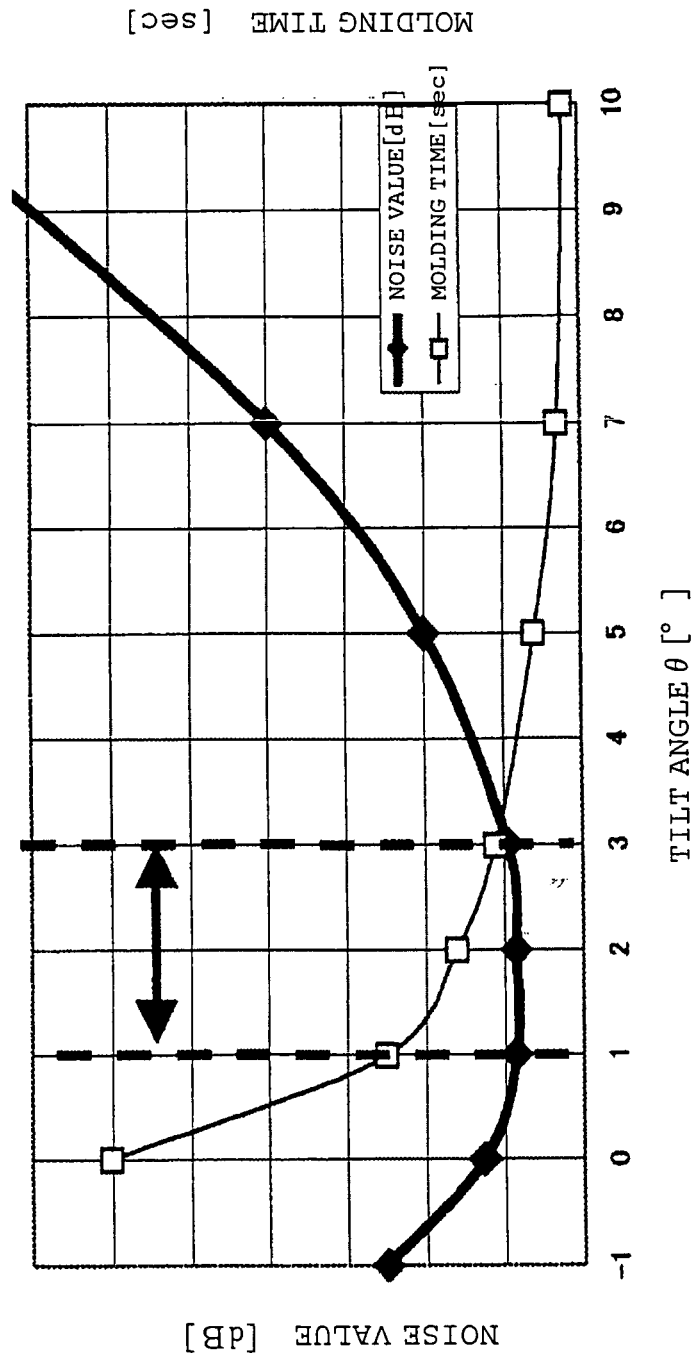


FIG. 13

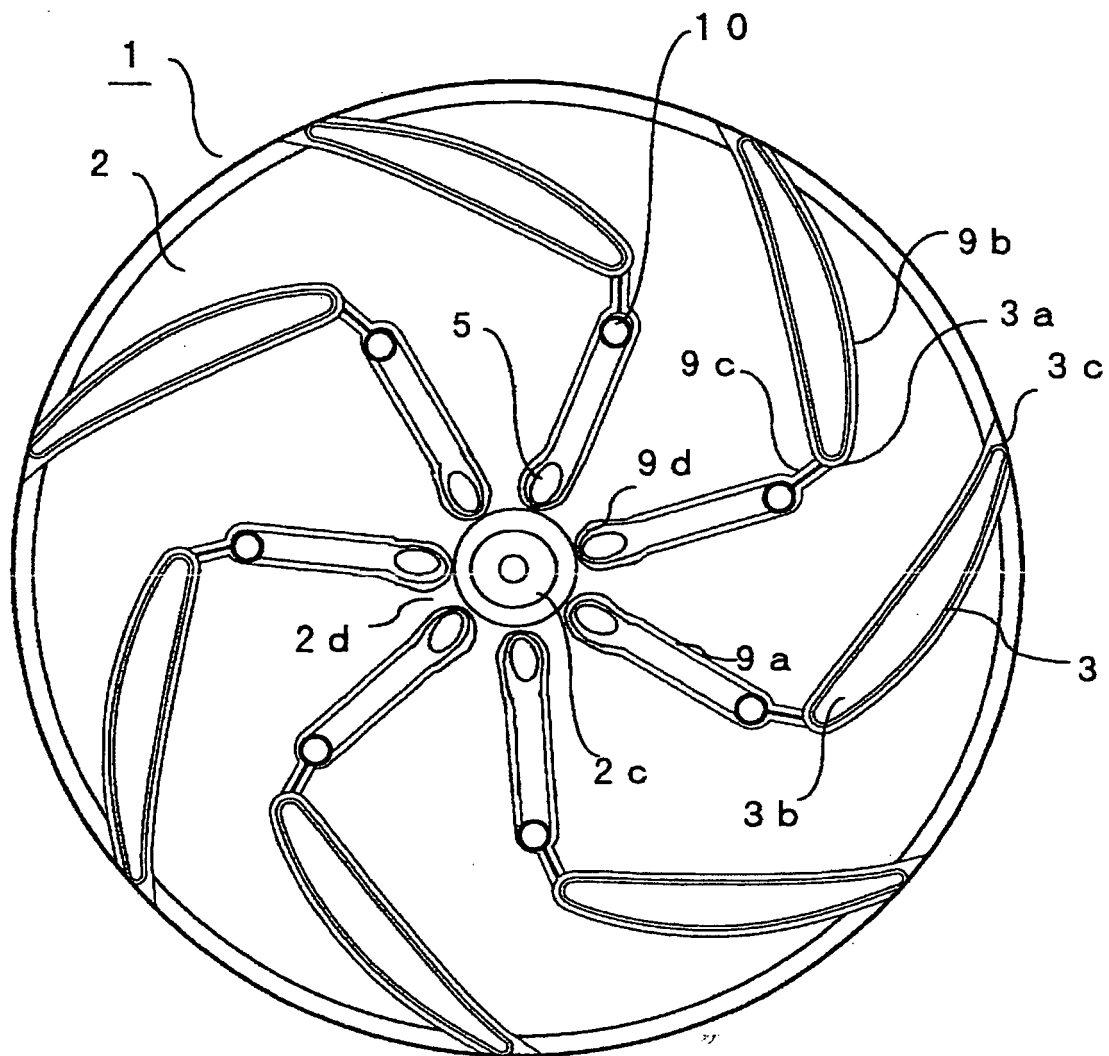


FIG. 14

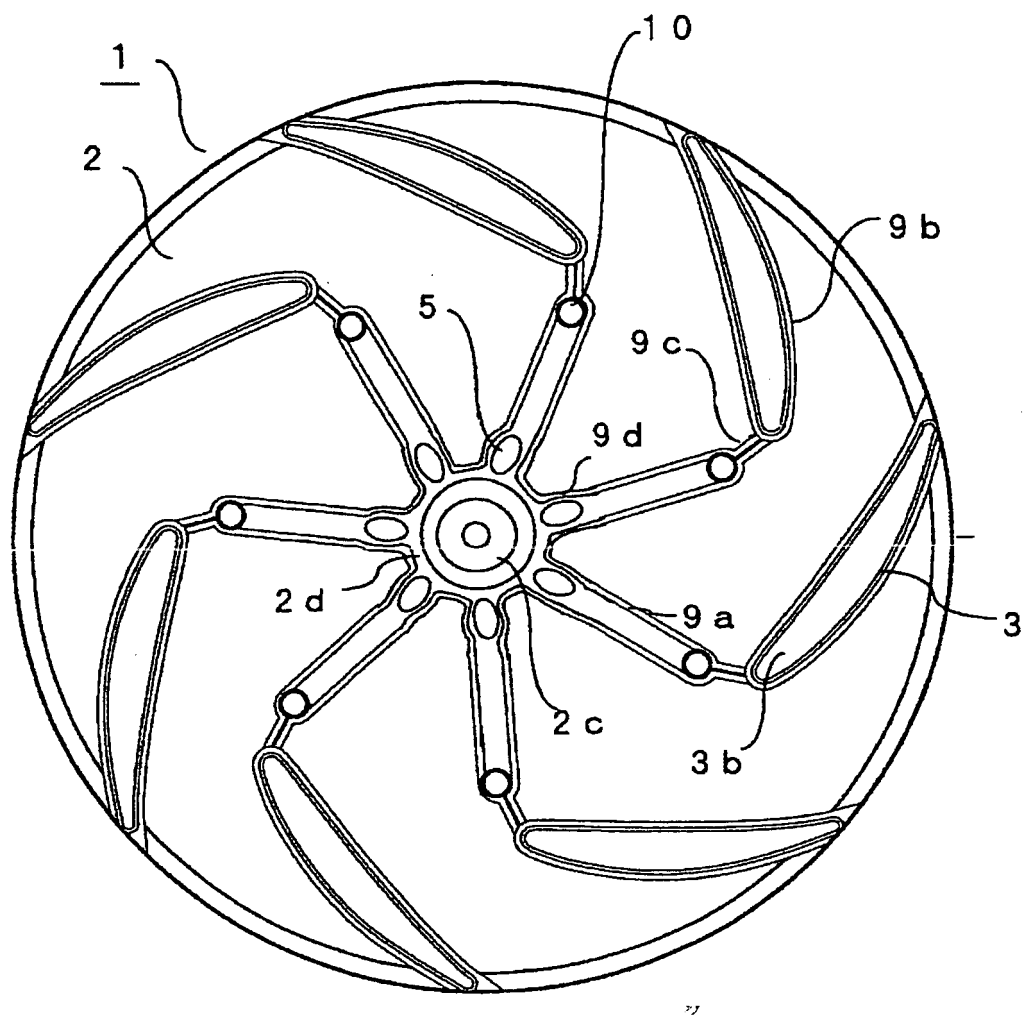


FIG. 15

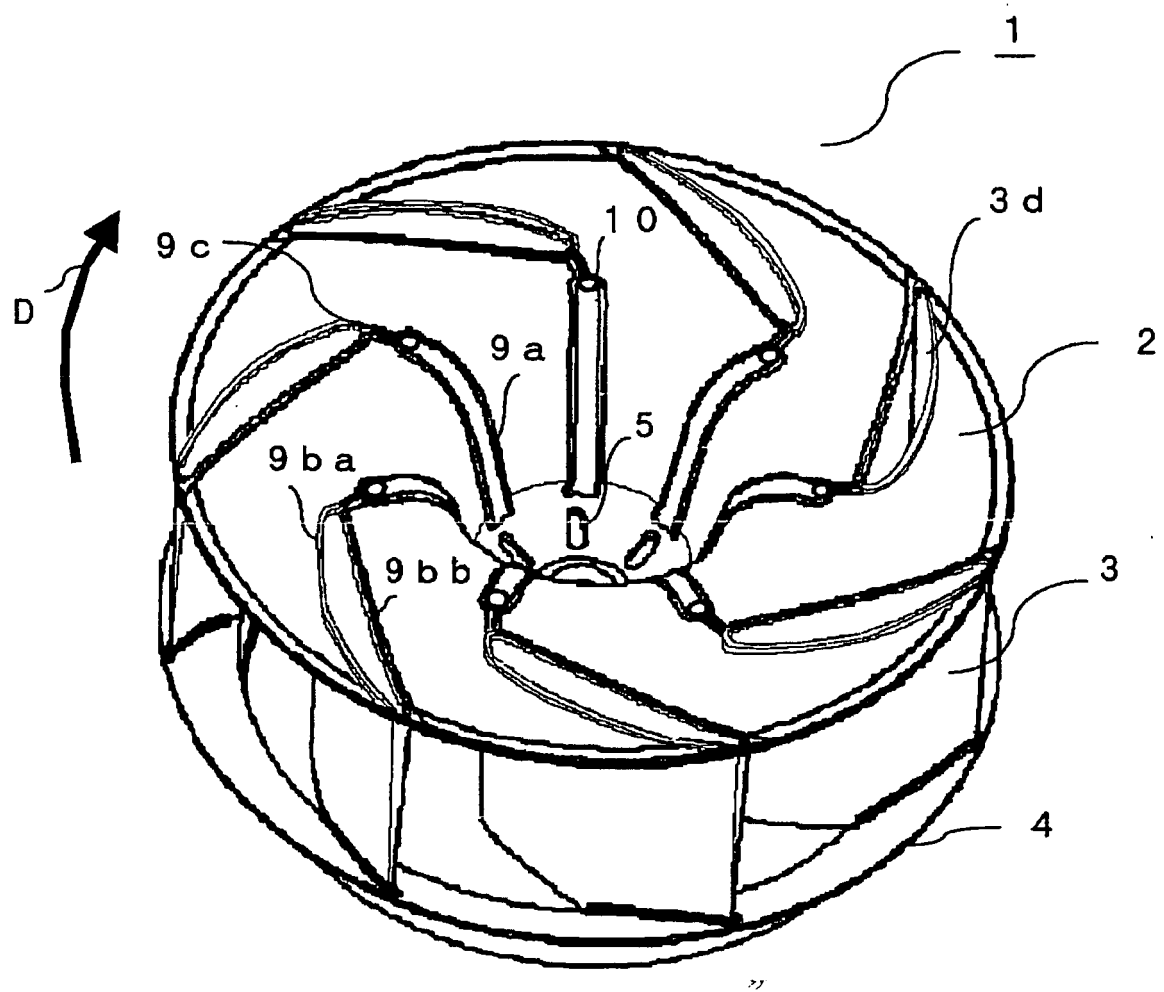


FIG. 16

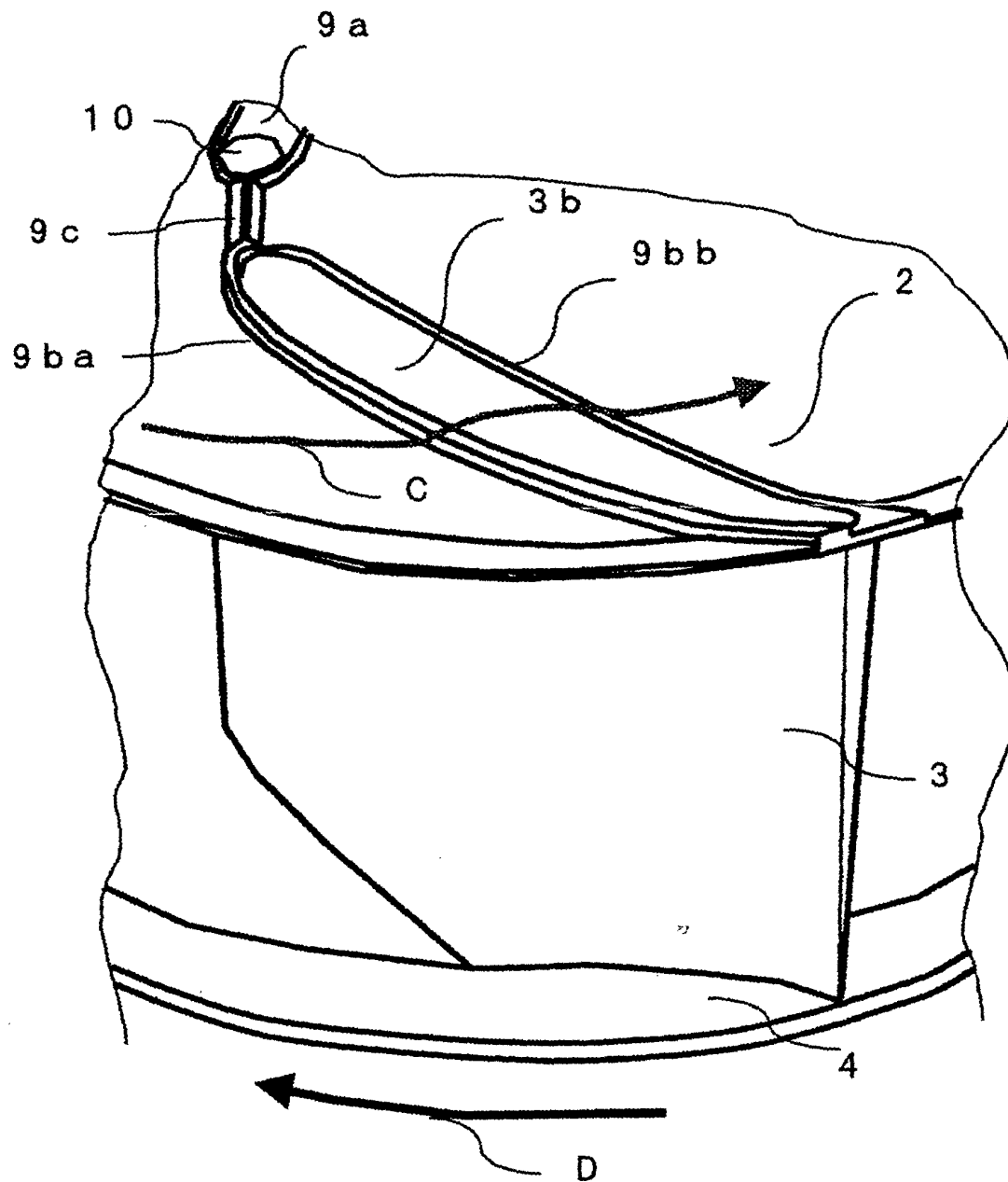


FIG. 17

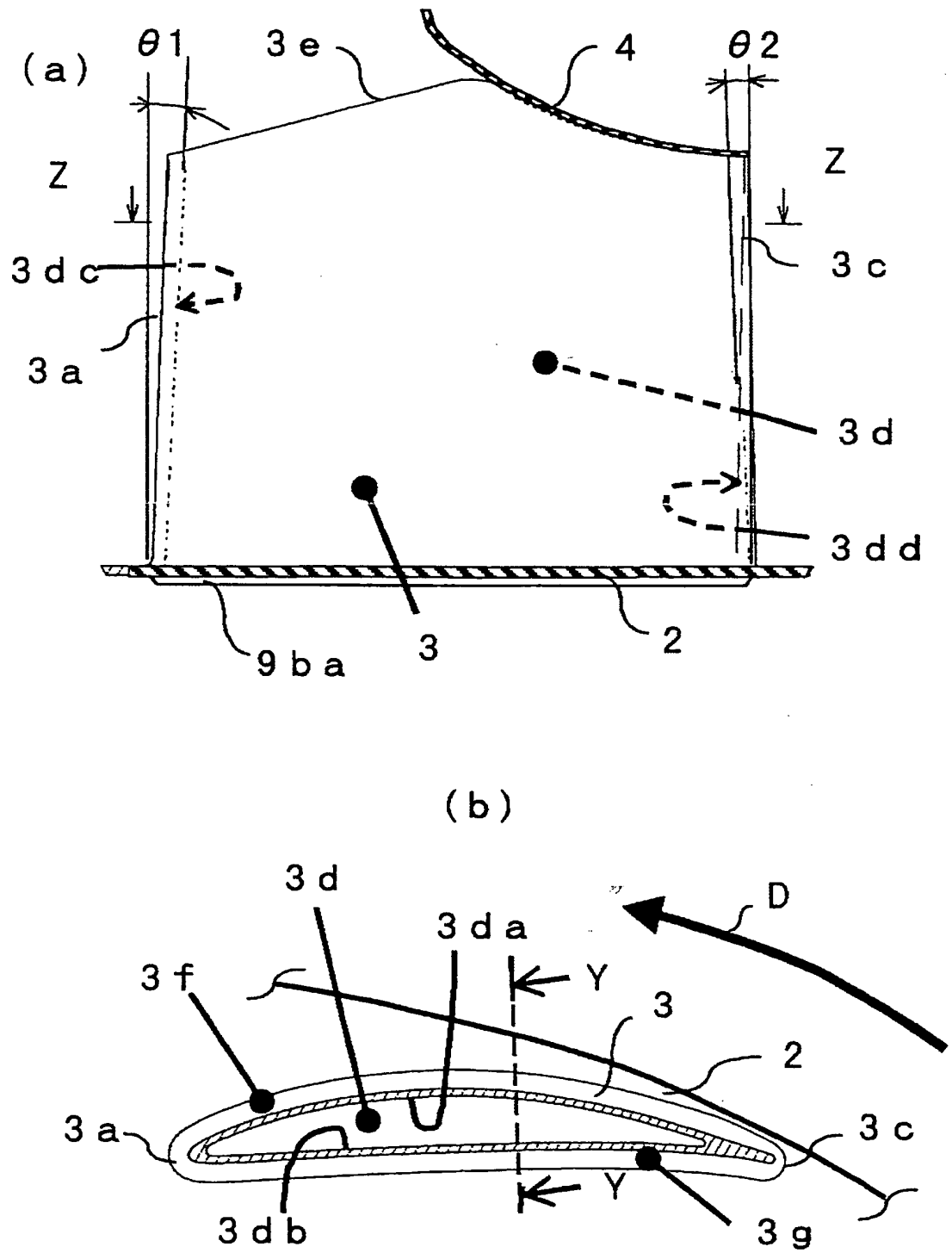
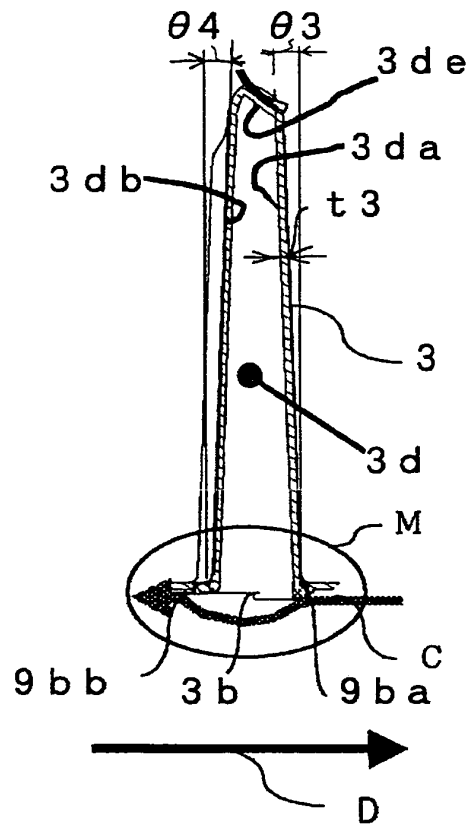


FIG. 18

(a)



(b)

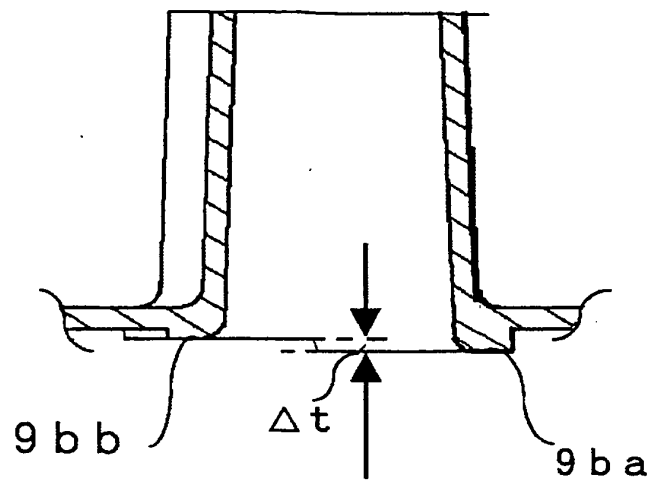


FIG. 19

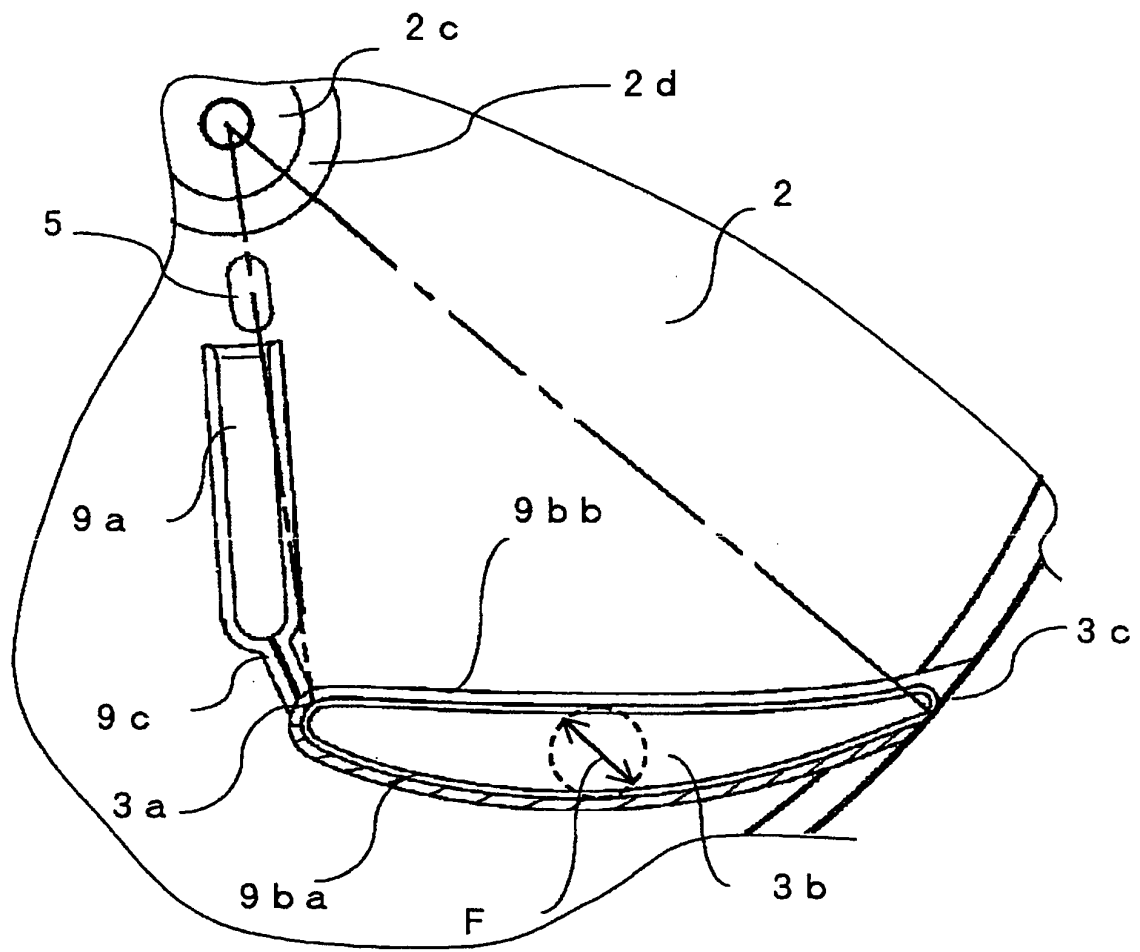


FIG. 20

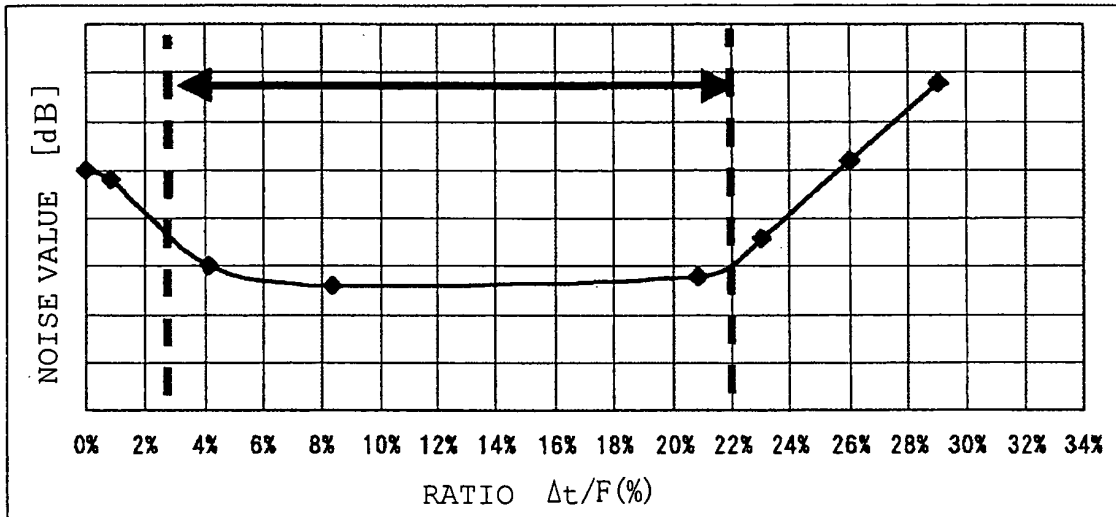


FIG. 21

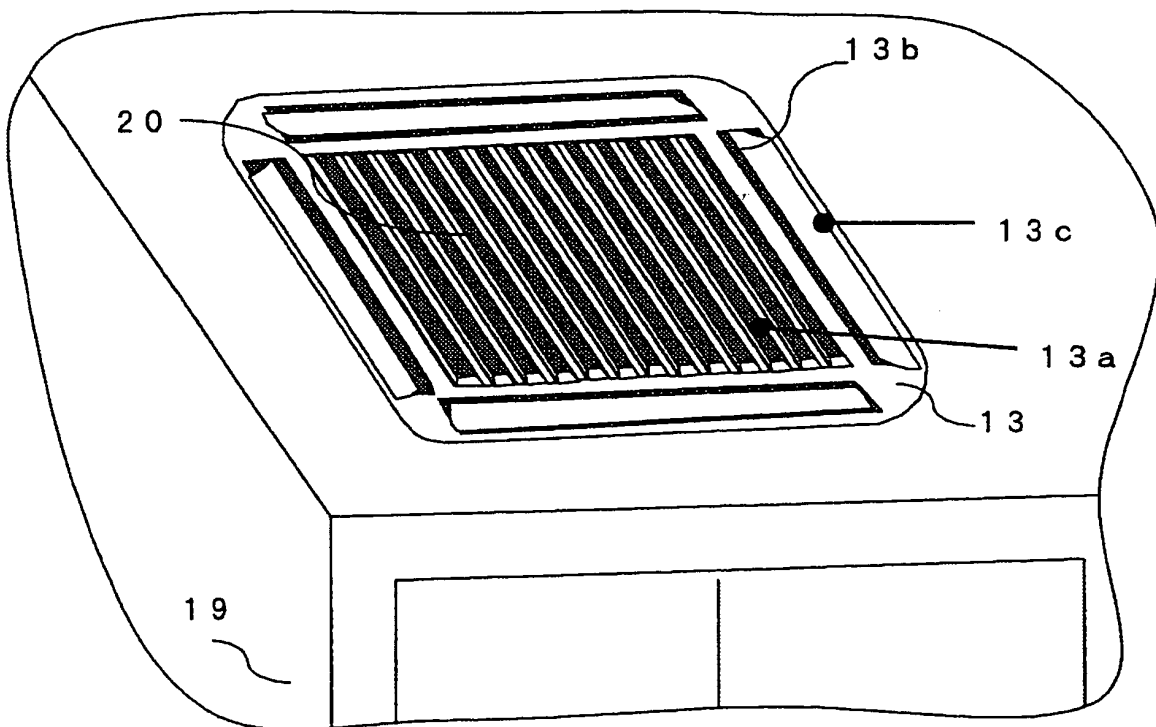


FIG. 22

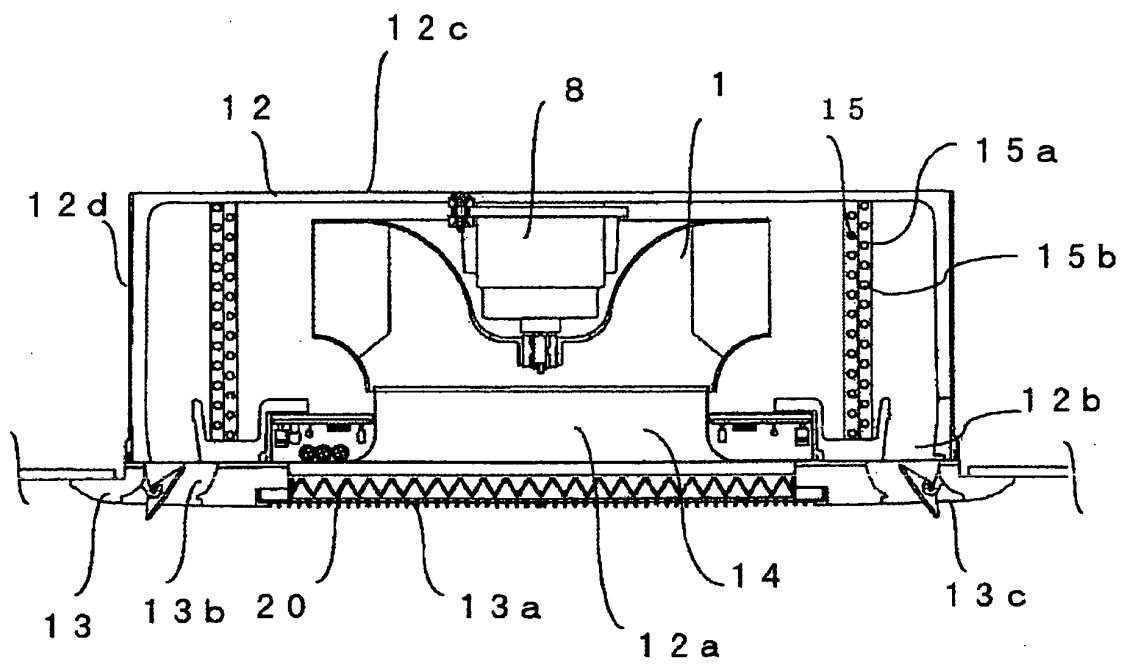
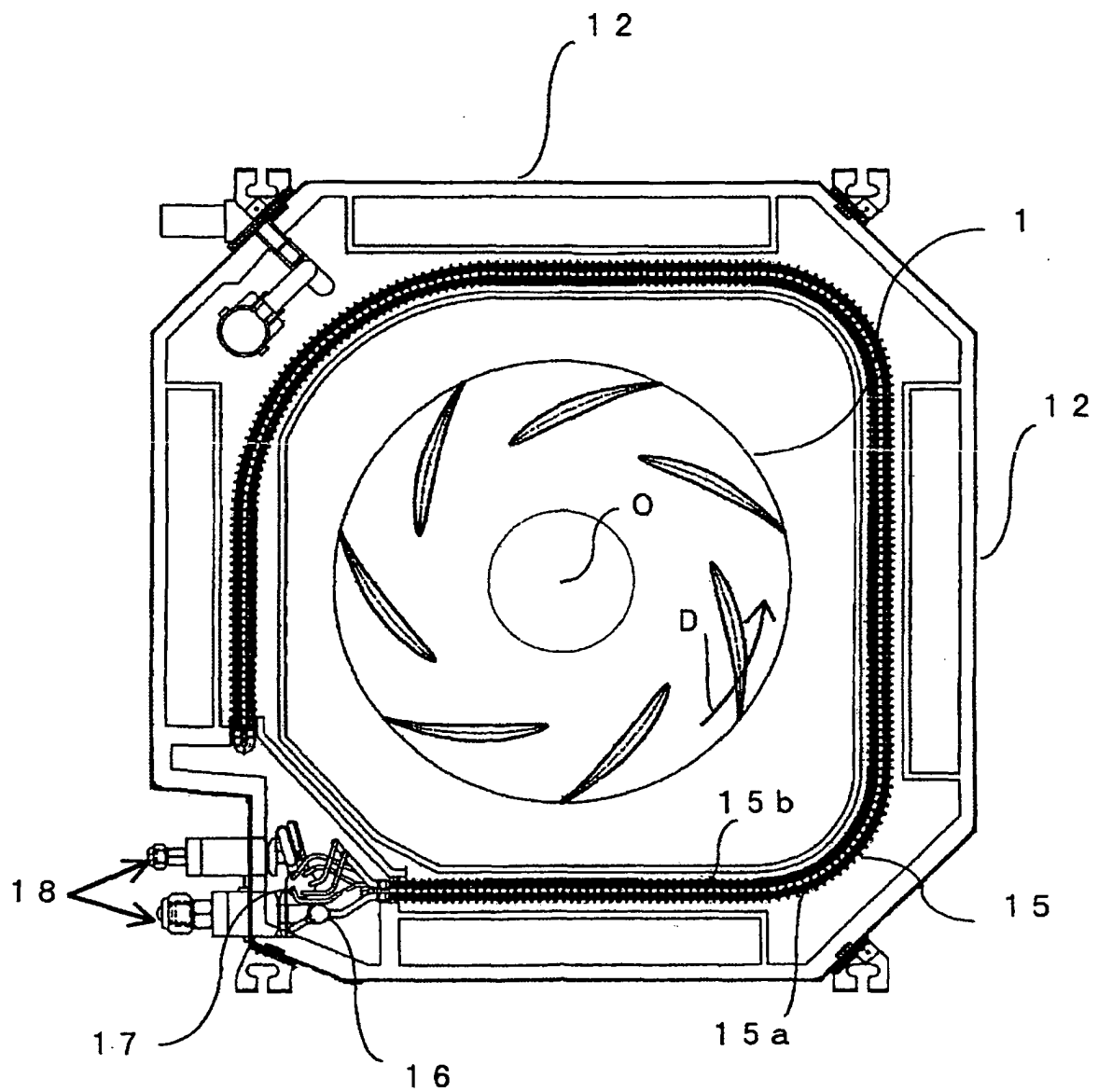


FIG. 23



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/319832

A. CLASSIFICATION OF SUBJECT MATTER <i>F04D29/28(2006.01) i, F04D29/30(2006.01) i, F24F1/00(2006.01) i</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) <i>F04D29/28, F04D29/30, F24F1/00</i>		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched <i>Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006</i> <i>Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006</i>		
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.
A	JP 3589243 B2 (Daikin Industries, Ltd.), 17 November, 2004 (17.11.04), Full text; Fig. 4 & WO 2003/087582 A1	1-16
A	JP 11-235722 A (Hitachi, Ltd.), 31 August, 1999 (31.08.99), Full text; Figs. 9, 10 (Family: none)	1-16
☐ 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 05 December, 2006 (05.12.06)		Date of mailing of the international search report 12 December, 2006 (12.12.06)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/319832

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 inventions in Claims 1-12 relate to the resin runners of the turbo fan formed of a thermosetting resin.

The inventions in Claims 13-16 relate to the turbo fan having the hollow blades.

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 an additional fee, this Authority did not invite payment of any additional fee.
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.:

Remark on Protest
the

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, 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)) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3131625 A [0002]
- JP 4116698 A [0002] [0005]
- JP 3544325 B [0002] [0006]
- JP 4116699 A [0002] [0007]
- JP 3131625 B [0004]