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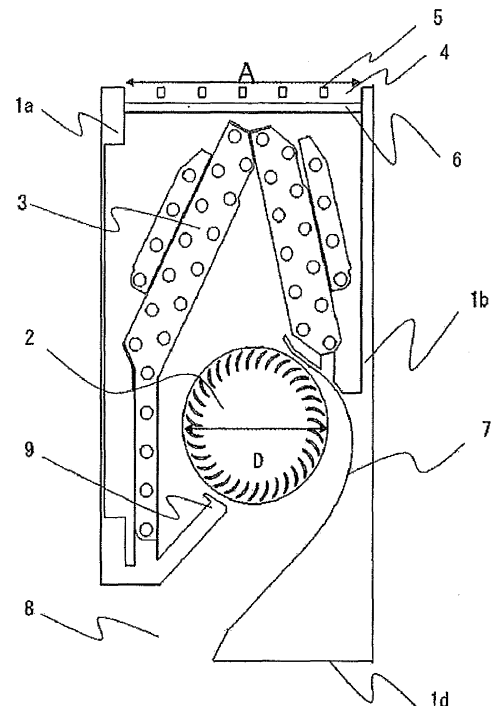
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(54) **FAN UNIT AND AIR CONDITIONER EQUIPPED WITH FAN UNIT**

(57) An air-conditioning apparatus is disclosed that is provided with an air-sending device that includes: a housing (1); a fan (2) that is disposed in the housing (1); a casing (7) that guides an airflow, the casing (7) arranged adjacent to the back side of the fan (2); and a stabilizer (9) that stabilizes the circular vortex, the stabilizer (9) arranged adjacent to the front side of the fan (2). When $\delta = A/D$ expressed by an air flow inlet port (4) width A and a fan diameter D is 2 or lower, an outer peripheral blade inflow angle $\beta = \delta \times \gamma$ radian is in the range of $0.4 \geq \gamma \geq 0.3$. The air-conditioning apparatus provided with an air-sending device is capable of suppressing noise as well as increasing fan performance even when the inlet port (4) is narrow.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a fan and an air-conditioning apparatus provided with the fan, and, more particularly, relates to a shape of a housing, a shape of a blade (blade, hereinafter also referred to as a blade) of a cross flow fan (tangential fan, hereinafter only referred to as cross flow fan) housed in the housing, and a shape of a casing, which guides an air flow, arranged adjacent to the fan.

Background Art

[0002] Typically, a cross flow fan is widely used as an air blowing mechanism of air-conditioning apparatus, and includes a housing, a cross flow fan housed in the housing, a casing, which guides an air flow, arranged on a back side of and adjacent to the cross flow fan, and a stabilizer, which stabilizes a circular vortex, arranged on a front side of and adjacent to the cross flow fan.

[0003] When the cross flow fan is used as such an air blowing mechanism of the air-conditioning apparatus, it is often the case that the housing of the cross flow fan is substantially a rectangular parallelepiped. The rectangular parallelepiped includes a plurality of rigid sides for supporting the housing, at least one outlet side provided with an air outlet port (hereinafter also referred to as an outlet), and at least one inlet side provided with an air inlet port (hereinafter also referred to as an inlet), and the respective sides are set such that the total number of sides are six.

[0004] In this case, since the housing will have high rigidity and will be able to hold the load in a stable manner, the side of the rectangular parallelepiped having the largest area is often used as the rigid side. It is desirable to make the air inlet port as large as possible from a viewpoint of air intake efficiency.

For this reason, two sides, which are the side opposite to the rigid side having the largest area and the side that has the second largest area, are typically used as the inlet sides. Further, a lattice-like grille is usually provided to the inlet port so as to conceal the inner structure of the housing and to prevent fingers from penetrating through.

[0005] Generally, the air outlet port is provided in another side that has the second largest area, and the two sides having the smallest area are used as the rigid sides. In such a cross flow fan, air from the air inlet ports on an upper side and a front side of the housing passes through pressure loss elements such as a filter and a heat exchanger and flows into the cross flow fan; the total pressure is elevated inside the cross flow fan, and the air is blown out to a casing side. The rotation speed of the cross flow fan needs to be increased when a high air volume cannot be obtained. Accordingly, noise increases.

[0006] An example of an air-conditioning apparatus

has been disclosed in which noise is suppressed while improving fan performance by specifying the positional relation between the rear gap created by the rear guider and the front gap created by the front guider and by specifying the angle made by the horizontal line and the line connecting the rotation center of the cross flow fan and the rear gap, as well as specifying the position of the tongue portion of the front guider (see PLT 1, for example).

[0007] Additionally, an example of a cross flow fan including a plurality of impellers, in which a plurality of blades are held by end plates on both sides and support plates in a middle portion, connected together has been disclosed. When an outer peripheral blade angle is B_o , an inner peripheral blade angle is B_i , the number of blades is Z , and a pitch chord ratio is T , the example has disclosed the relationship of the outer peripheral blade angle B_o , the inner peripheral blade angle B_i , the number of blades Z , and the pitch chord ratio T of the cross flow fan in order that the cross flow fan will have a high air volume and a high pressure while having a low noise (see PLT 2, for example).

[0008] Furthermore, an air-conditioning apparatus has been disclosed that includes a cross flow fan and a stabilizer separating the suction side passage and the discharge side passage of the cross flow fan. The stabilizer includes: a tongue portion that extends towards the rotation direction of the cross flow fan in which the side of the tongue portion opposing the cross flow fan is formed so that it reduces its clearance gap with the outer circle of the cross flow fan gradually towards the rotation direction of the cross flow fan; and a protruding portion that protrudes towards the interior of the cross flow fan, that is formed at the end portion of the tongue portion such that the clearance gap between the outer circle of the cross flow fan and the tongue portion becomes smallest, and that has a substantially triangular cross-sectional shape when taken along a line perpendicular to the direction of the fan axis where the clearance gap with the cross flow fan is the smallest.

The protrusion height H_s of the protruding portion from the side of the tongue portion opposing the cross flow fan is configured to be 25 % to 35 % of the dimension G 1 of the minimum clearance gap between the outer circle of the cross flow fan and the side of the tongue portion opposing the cross flow fan, and the angle of the apical angle of the protruding portion is configured to be 50° to 75° (see PTL 3, for example).

[0009] However, all of the above-mentioned conventional fans are examples based on a case in which the inlet area is made to be as large as possible. In these conventional fans, when the width of the air inlet port provided at the top side and front side of the housing is A , the diameter of the cross flow fan is D , and the size factor δ of the cross fan is defined as $\delta = A / D$, then the width A of the air inlet port provided at the top side and front side of the housing is sufficiently wide against the diameter D of the cross flow fan and the size factor δ of

the cross fan is typically about 3 to 4. Accordingly, stable air can be supplied without occurrence of excessive negative pressure and drift in the air inlet port while air flows into the cross flow fan.

[0010] The aesthetic appearance of the front side of the housing has a large influence on consumers. Accordingly, there has been a strong demand for a configuration with no inlet on the front side. Further, there has also been a strong demand for the miniaturization of the product and hence, it is necessary to make the size factor δ of the cross flow fan small.

[0011] In such a case, when the inlet is narrowed while having the same configuration as that of the conventional fan as described above, an excessively large negative pressure or drift is generated when air flows into the cross flow fan, and thus the flow is changed. The angle between the blade of the cross flow fan and the flow direction becomes large, and, as a result, momentum transfer efficiency of the blade to the fluid reduces, the fan performance is hindered, as well as the increase in pressure fluctuation and noise.

Further, as the result of narrowing the inlet port, air pushed out from the blade of the cross flow fan drifts to the inlet port side, and, hence, the flow in a cross section of the cross flow fan becomes unstable, whereby the air flow impinges on the normal direction of the surface of the casing and loss is increased. The invention provides a fan disposed with a cross flow fan that can overcome the above drawbacks, and a cross flow fan with high air volume and high pressure as well as low noise even when an air inlet port is narrow.

Citation List

Patent Literature

[0012]

- PTL 1: Japanese Unexamined Patent Application Publication JP-A-2007-040 544
 PTL 2: Japanese Unexamined Patent Application Publication JP-A-6-323 294
 PTL 3: Japanese Unexamined Patent Application Publication JP-A-2004-150 789

Summary of the Invention

Technical Problem

[0013] The invention has been made to overcome the above-mentioned drawbacks, and an object thereof is to provide a fan that is capable of suppressing noise as well as increasing fan performance even with a fan with a narrow air inlet port such that $\delta = A/D$ is 2 or less (where the width of the air inlet port is A, the diameter of the cross flow fan is D, and the size factor δ of the cross fan is defined as $\delta = A / D$) by specifying an outer peripheral blade inflow angle that influences the air intake efficiency

of the blade of the cross flow fan.

Solution to the Problem

- [0014]** An fan according to the invention includes: a housing including an inlet port and an outlet port; a cross flow fan disposed in the housing; a casing arranged on a back side of the cross flow fan, the casing constituting a part of the outlet port; and a stabilizer arranged on a front side of the cross flow fan, the stabilizer opposing the casing and constituting a part of the outlet port, in which, where A is a maximum inlet width of the inlet port in a direction substantially orthogonal to a rotation axis of the cross flow fan, D is a diameter of the cross flow fan, β is an outer peripheral blade inflow angle,

$$\beta = (A / D) \gamma \text{ (radian)},$$

- in which $A / D \leq 2$ and $0.4 \geq \gamma \geq 0.3$ is defined.

Advantageous Effects of Invention

- [0015]** According to the invention, a fan that is capable of suppressing noise as well as increasing fan performance even when the air inlet port is narrow can be obtained.

Brief Description of the Drawings

[0016]

- FIG. 1 is a cross-sectional view of an air-conditioning apparatus provided with a fan according to Embodiment 1 of the invention.
 FIG. 2 is a perspective view of the air-conditioning apparatus provided with the fan according to Embodiment 1 of the invention.
 FIG. 3 is an enlarged cross-sectional view of the periphery of a cross flow fan related to the fan according to Embodiment 1 of the invention.
 FIG. 4 is a cross-sectional view showing a single piece of blade of the cross flow fan related to the fan according to Embodiment 1 of the invention.
 FIG. 5 is a diagram showing, in percentage, efficiency of the fan according to Embodiment 1 of the invention.
 FIG. 6 is a total pressure distribution diagram of air flow in the fan according to Embodiment 1 of the invention.
 FIG. 7 is a diagram showing fanning efficiency of the fan according to Embodiment 1 of the invention.
 FIG. 8 is an enlarged cross-sectional view of the periphery of a cross flow fan related to a fan according to Embodiment 2 of the invention.

- FIG. 9 is an enlarged cross-sectional view of the periphery of the cross flow fan of the fan according to Embodiment 2 of the invention showing an enlarged area ratio.
- FIG. 10 is a diagram showing, in percentage, efficiency of the fan according to Embodiment 2 of the invention.
- FIG. 11 is a comparison of total pressure distribution diagrams of air flows in the fans according to Embodiment 2 of the invention.
- FIG. 12 is a diagram showing fanning efficiency of the fan according to Embodiment 2 of the invention.

Description of Embodiments

Embodiment 1

[0017] Next, embodiments of the invention will be explained with reference to the drawings. In the drawings described hereinafter, identical or similar parts will be given same or similar reference numerals. It should be noted that the drawings are schematic, and ratios of dimensions and the like are different from the actual ones. Accordingly, specific sizes and the like should be determined by referring to the descriptions given below. Further, it is needless to say that the dimensional relationships and ratios between the drawings may differ in some portions.

[0018] FIG. 1 is a cross-sectional view of an air-conditioning apparatus provided with a fan according to Embodiment 1 of the invention. Further, FIG. 2 is a perspective view of the air-conditioning apparatus provided with the fan according to Embodiment 1 of the invention. A housing 1 in the drawings includes: a front panel 1a, which is one of a plurality of rigid sides supporting the housing 1, and is positioned at the front portion of the housing 1; a rear panel 1b, which is another one of the plurality of rigid sides, and is positioned opposite the front panel 1a; upper panel 1c, which is an inlet side provided with an air inlet port 4, and is positioned at the top portion of the housing 1; a bottom panel 1d, which is an outlet side provided with an air outlet port 8, and is positioned opposite to the upper panel 1c; and left and right side panels 1e and 1f, which are among the plurality of rigid sides supporting the housing 1, and are positioned at the side portions of the housing 1.

[0019] A cross flow fan 2 having a plurality of blades oriented in the fan rotation direction is arranged inside the housing 1, and heat exchangers 3 that are arranged in an inverted V-shape are provided in an air flow on the inlet side of the cross flow fan 2. The heat exchangers 3 control temperature of air sucked from the outside into the cross flow fan 2 through gaps of an inlet grille 5, which is provided in the air inlet port 4, and a filter 6.

The casing 7 enlarges as it approaches the bottom panel 1d and is positioned on substantially the rear side and downstream of the cross flow fan 2. The casing 7 con-

stitutes an outlet side passage leading to the outlet port 8 to send out air that has been heat exchanged in the heat exchangers 3 to the room.

A stabilizer 9 is positioned adjacent to and facing the front side and substantially the bottom portion of the cross flow fan 2, and separates the inlet side passage and the outlet side passage of the cross flow fan 2. Symbol A indicates a maximum inlet width of the inlet port 4 in the direction substantially orthogonal to the rotation axis of the cross flow fan 2, and symbol D indicates a diameter of the fan.

[0020] As illustrated in Figs. 1 and 2, the fan that is provided with the cross flow fan 2 configured as above has a front panel 1a that is detachably disposed so that the filter 6 can be removed, but during sending of air, the front panel 1a is fixed at a position depicted in the figures. During operation of the fan, the cross flow fan 2 rotates clockwise. When the cross flow fan 2 rotates, air in the room is sucked through the gap of the inlet grille 5 provided in the air inlet port 4, large dusts in the air are removed by the filter 6, and the air is split and is made to pass through the front side and the rear side of the heat exchanger 3.

The air that has passed through the heat exchanger 3 is cooled or heated, and then is sucked into the cross flow fan 2. Then, air that is blown out from the cross flow fan 2 to the casing 7 side is sent toward the outlet port 8 of the housing that opens in an oblique downward direction and is discharged into the room.

[0021] FIG. 3 is an enlarged cross-sectional view of the periphery of the cross flow fan related to the fan according to Embodiment 1 of the invention. Further, FIG. 4 is a cross-sectional view showing a single piece of blade of the cross flow fan related to the fan according to Embodiment 1 of the invention. In FIG. 3, the cross flow fan 2 includes a plurality of blades 10. In this embodiment, the cross flow fan 2 includes 35 pieces of blades 10. Although the intervals of the blades 10 may be set equidistantly, non-equidistantly or at random, it is necessary to arrange the blades 10 such that favorable fanning efficiency is obtained.

[0022] In FIG. 4, an arrow B indicates the rotation direction, a dotted line C indicates a trajectory of an outer peripheral side of the blades 10, and a dotted line E indicates a trajectory of an inner peripheral side of the blades 10. The blade 10 includes a blade outer side 10a that is substantially arcuate and a blade inner side 10b that is substantially arcuate, and is arranged such that the blade inner side 10b is oriented toward the rotation direction of the blade 10.

Here, the angle between the tangential line at the distal end portion of the blade 10 on the trajectory of an outer peripheral side of the blade, which is the trajectory of the distal end side of the blade 10, and the tangential line at a tip of the arc of the blade outer side 10a is denoted as an outer peripheral blade inflow angle β .

[0023] In FIG. 5 are results of a fractional factorial design based on design of experiments conducted to investigate the γ that increases the fanning efficiency of

the fan according to Embodiment 1 of the invention, when a maximum inlet width of the air inlet port in the direction substantially orthogonal to a rotation axis of the cross flow fan is A, a diameter of the cross flow fan is D, an outer peripheral blade inflow angle β is defined by $\beta = (A/D) \gamma$ (radian) in which $A/D \leq 2$.

Fig. 5 shows the comparison results in percentage, in which the percentage is against the value that had the highest efficiency in the Embodiment. In the drawing, a performance ratio (%) is taken on an axis of ordinates and a value of γ is taken on an axis of abscissas. Here, symbol F indicates a preferable range of γ of the fan of Embodiment 1 according to the invention.

[0024] In the fractional factorial design based on the design of experiments, an experimental method using orthogonal arrays, in which only the factors that have significant effects are sampled by uniformly changing the multiple factors in the experiment corresponding to the full factorial design, will be conducted. The reliability of the optimum value obtained by the fractional factorial design will be confirmed by analysis of variance and by conducting an F test, and accordingly will be statistically supported by the level of significance.

In Embodiment 1 of the invention, the shape factors contributing to the efficiency of the air flow path and the blade was estimated in 4374 ways by conducting 18 experiments analyzing 8 factors based on L18 orthogonal arrays. With the above method, it has been confirmed that the optimum value of γ is in a range of $0.4 \geq \gamma \geq 0.3$. The level of significance was verified to be 1 % or less with the F test, and thus it has been confirmed that the optimum value is statistically significant at 99 %.

[0025] In the conventional art, γ is, typically, 0.28 or less in view of preventing the momentum transfer efficiency to the fluid from dropping, which is caused by the acute angle between the blade of the fan and the flow of air. That is, when (A/D) takes a value close to the minimum value 1, β is 0.28 radian or less when γ is 0.28 or less. This means that the outer peripheral blade inflow angle β is 16.1° or less. When the outer peripheral blade inflow angle β is less than 20°, the transfer of momentum by the blade to the fluid remarkably drops, and it will be necessary to increase the rotation speed. Hence, a fan is not configured to have γ that is 0.28 or less.

[0026] Further, it is when β is an extremely large value or (A/D) is an extremely small value, when γ is 0.43 or more. Suppose (A/D) takes the maximum value 2, then β is 0.86 radian or more when γ is 0.43 or more, and accordingly the outer peripheral blade inflow angle β is 49.3° or more. In this case, the angle of the blade of the fan against the air flow is acute, and the momentum transfer efficiency to the fluid drops.

[0027] In contrast, when (A/D) takes the minimum value and supposing $(A/D) = 1$, then the inlet width A and the fan diameter D will be the same. In general, the width of an air flow path of a fluid machinery is desirably constant to prevent loss caused by contraction flow or expansion flow. From this aspect, it is desirable that an inlet

width A is half the length of the circumference, in which $A = \pi$ (circular constant ≈ 3.14) $\times D$, that is, $(A/D) = \pi$.

Since the loss caused by the contraction flow or the expansion flow increases in proportion to the flow velocity to the power of 2, when $(A/D) = 1$, then the loss will be π to the power of 2 (9.87 times) compared to a case in which the air flow path is constant. Thus, it will be difficult to function as a machine. Accordingly, there is generally no fan in which γ is 0.43 or more.

[0028] FIG. 6 is a total pressure distribution diagram of air flow in the fan according to Embodiment 1 of the invention when, for example, $\delta = A/D = 1.7$, $\beta = \delta \times \gamma = 1.675 \times 0.3 = 0.55$ (radian). In the drawing, a portion surrounded by a dotted line G indicates a part where the air flow is obstructed.

Performance drops in conventional fans since the standing vortex that obstructs the air flow exists considerably on the casing 7 side from the region connecting the stabilizer 9 and the center axis of the cross flow fan 2. However, in Embodiment 1, the position of the standing vortex is changed to a position substantially in the region connecting the stabilizer 9 and the center axis of the cross flow fan, and thus a flow field where there is no obstruction of flow is formed.

[0029] FIG. 7 shows a relationship between shaft power and fluid energy of the cross flow fan. The fanning efficiency is higher, the greater the inclination. In the drawing, fluid energy (W) is taken on an axis of ordinates and shaft power (W) is taken on an axis of abscissas. Here, it is illustrated that the fan of Embodiment 1 of the invention has a greater inclination compared to that of the conventional fan.

It has been confirmed by an experiment on the improvement effect of the flow field in FIG. 6 that the fanning efficiency is substantially greater than that of the conventional art. It is confirmed that the rotation speed can be lower for obtaining the same air volume, and, as a result, noise can be reduced.

[0030] In the fan shown in Embodiment 1 of the invention in which the air inlet port 4 is narrow such that $\delta = A/D$ is 2 or less, by setting the outer peripheral blade inflow angle β of the blade 10 of the cross flow fan 2 within a preferable range, the angle between the blade 10 of the cross flow fan 2 and the air flow in its flow direction can be optimized. Accordingly, the momentum transfer efficiency of the blade 10 to the fluid and the fan performance are enhanced, and, as a result, the input energy can be suppressed and, consequently, noise and vibration can be reduced.

Although in Embodiment 1 of the invention, description has been made with respect to an air-conditioning apparatus, substantially the same effects can be obtained with other apparatus with a fan mechanism with no heat exchanger or a filter.

Embodiment 2

[0031] In the above Embodiment 1, a configuration of

a fan has been disclosed in which generation of noise is suppressed while increasing fan performance when the air inlet port 4 is narrow by specifying the range of the outer peripheral blade inflow angle β . In Embodiment 2 of the invention, the configuration of the fan will be specified by a function $r(\theta)$ that is defined based on a distance and angle from a rotation center of a cross flow fan, where θ is an angle from a starting portion of a curve of an enlarged air flow path of a casing.

[0032] FIG. 8 is an enlarged cross-sectional view of the periphery of the cross flow fan related to the fan according to Embodiment 2 of the invention. It should be noted that configuration and operation of an air-conditioning apparatus provided with the fan of Embodiment 2 of the invention are the same as that of the aforementioned Embodiment 1, and description thereof will be omitted.

[0033] In FIG. 8, a casing 7 is formed integrally with a rear panel 1b of a housing 1 or is formed so as to be mountable to the rear panel 1b, and is disposed in a substantially curved shape so as to guide flow of air along an air flow discharge portion of a cross flow fan 2.

The shape (the curve constituting the air flow path) of the casing 7 may be specified, based on the distance and angle from the rotation center of the cross flow fan 2, by the function $r(\theta) = r_0 \times \exp(\theta \times \tau)$, where r_0 is distance from the rotation center of the cross flow fan 2 to the starting portion of the curve of the enlarged air flow path of the casing 7, θ is the center angle from the start portion of the cross flow fan 2, and τ is a constant related to the enlarged area ratio τ .

[0034] FIG. 9 is an enlarged cross-sectional view of the periphery of the cross flow fan related to the fan according to Embodiment 2 of the invention showing an enlarged area ratio τ . In the drawing, the enlarged area ratio is a ratio obtained by dividing the enlarged air flow path area ($A1 + A2$) by a sector area ($A2$) that has a radius r_0 from the rotation center of the cross flow fan 2 and a center angle of 90° .

The enlarged area ($A1 + A2$) is an area surrounded by the curved line made by the enlarged air flow path of the casing 7, the line connecting the rotation center of the cross flow fan 2 to the starting portion (here, the starting portion is the portion indicating the starting point of the enlarged air flow path of the casing 7, which is defined by an arbitrary angle of $0 \leq \theta_1 \leq 90$ against the direction orthogonal to the direction from the rotation center of the cross flow fan 2 to the air intake port 4, and defined by the portion having the distance r_0 from the rotation center of the cross flow fan), and a point where a straight line intersects the curved line of the enlarged air flow path, the straight line being a line that is, with respect to the rotation center of the cross flow fan, 90° from the line connecting the rotation center of the cross flow fan 2 to the starting portion.

[0035] That is, the enlarged area ratio τ is obtained as a ratio between an integral value of the function $r(\theta)$ for a region between the enlarged air flow path start angle

θ_1 and the angle θ_2 , which is an angle with respect to the direction extending from the center of rotation of the cross flow fan 2 perpendicular to the direction of the air inlet port 4 with an angle θ from the start portion, and an integral value of a sector portion of the circle.

In general, the enlarged area ratio τ is expressed by enlarged area ratio $\tau = (\exp(2 \times \tau \times \theta_2) - \exp(2 \times \tau \times \theta_1)) / (2 \times \tau \times (\theta_2 - \theta_1))$. Particularly, when θ is 90° , the enlarged area ratio τ is expressed by enlarged area ratio $\tau = (\exp(2 \times \tau \times \pi/2) - \exp(2 \times \tau \times 0)) / (2 \times \tau \times \pi/2)$.

[0036] Here, in the technical field of fluid machinery, the function $r(\theta)$ is a function which determines the shape of a general air flow path referred to as a logarithmic spiral. The function $r(\theta)$ is a function induced from the equation of continuity assuming that the flow is uncompressed and is without any loss and from the equation of flow line which is induced from the nature of the constant flow angle of the enlarged air flow path in solving the law of conservation of an angular momentum.

[0037] In order to guide the air flow in the casing 7 and to favorably convert dynamic pressure into static pressure, it is necessary to change the degree of enlargement of the curve using the value of τ . However, the curve, which is induced from the formula, is solved based on the assumption that the flow is uncompressed without any loss. Thus, the flow line does not completely agree with the flow of the fluid machinery because, in practice, there will be a loss.

Accordingly, a straight line may be partially provided. In the fan of Embodiment 2 of the invention, the shape of the casing 7 is not specified by $r(\theta)$ but is specified by an enlarged area ratio of the air flow path which is of primary importance to the character of the enlarged air flow path.

[0038] In FIG. 10 are results of a fractional factorial design based on design of experiments conducted to investigate the τ that increases the fanning efficiency of the fan according to Embodiment 2 of the invention, when τ is a constant related to the enlarged area ratio τ , the starting portion is defined as the portion that is the most closest to the cross flow fan 2, r_0 is the distance from the rotation center of the cross flow fan 2 to the starting portion, θ is the rotation center angle from the starting point of the cross flow fan 2, and when, based on the distance and angle from the rotation center of the cross flow fan 2, function $r(\theta) = r_0 \times \exp(\theta \times \tau)$.

FIG. 10 shows the comparison results in percentage, in which the percentage is against the value that had the highest efficiency in the Embodiment. In the drawing, a performance ratio (%) is taken on an axis of ordinates and a value of τ is taken on an axis of abscissas. Here, symbol H indicates a preferable range of τ of the fan of Embodiment 2 according to the invention.

[0039] In the fractional factorial design based on the design of experiments, an experimental method using orthogonal arrays, in which only the factors that have significant effects are sampled by uniformly changing the multiple factors in the experiment corresponding to the full factorial design, will be conducted. The reliability of

the optimum value obtained by the fractional factorial design will be confirmed by analysis of variance and by conducting an F test, and accordingly will be statistically supported by the level of significance.

In Embodiment 2 of the invention, the shape factors contributing to the efficiency of the air flow path and the casing was estimated in 4374 ways by conducting 18 experiments analyzing 8 factors based on L18 orthogonal arrays. With the above method, it has been confirmed that the optimum value of τ to induce τ is in a range of $0.21 \geq \tau \geq 0.23$. The level of significance was verified to be 1 % or less with the F test, and thus it has been confirmed that the optimum value is statistically significant at 99 %.

[0040] Based on the above result τ , the range of the enlarged area ratio τ that increases the fanning efficiency has been compared in percentage based on the fractional factorial design of the design of experiments. In the conventional art, since τ is about 0.2 or 0.3, τ is 1.39 or 1.66, and only about 60% of the efficiency of the fan of Embodiment 2 is obtained.

On the other hand, by setting the enlarged area ratio τ to a range of $1.416 \geq \tau \geq 1.466$ for the fan of Embodiment 2, greater fanning efficiency is obtained compared with conventional fans. The rotation speed can be lower for obtaining the same air volume, and as a result, noise can be reduced.

[0041] FIG. 11 is a total pressure distribution diagram of air flow in the fan according to Embodiment 2 of the invention when $\delta = A/D = 1.7$, $\tau = 0.21$. In the drawing, FIG. 11(a) indicates the total pressure distribution diagram of air flow in the fan according to Embodiment 2 of the invention, and FIG. 11(b) indicates the total pressure distribution diagram of air flow in the fan of the conventional art. In the fan of the conventional art, an air flow blown out from the cross flow fan 2 generates a flow along the casing 7 and hence, efficiency is largely lowered due to viscosity loss with the wall.

However, with the configuration of the fan of Embodiment 2 according to the invention, the fastest velocity portion of the air flow is created at the center of rotation between the casing 7 and the stabilizer 9 which is close to the velocity distribution of that of the Poiseuille's flow in which pressure loss is low, and, thus, fanning efficiency is increased.

[0042] FIG. 12 shows a relationship between shaft power and fluid energy of the cross flow fan 2. The fanning efficiency is higher, the greater the inclination. In the drawing, fluid energy (W) is taken on an axis of ordinates and shaft power (W) is taken on an axis of abscissas. Here, it is illustrated that the fan of Embodiment 2 of the invention has a greater inclination compared to that of the conventional fan. It has been confirmed by an experiment on the improvement effect of the flow field in FIG. 11 that the fanning efficiency is substantially greater than that of the conventional art. It is confirmed that the rotation speed can be lower in obtaining the same air volume, and, as a result, noise can be reduced.

[0043] In the above-mentioned Embodiment, the ex-

planation has been made by focusing on the case where the curve of the casing 7 is a logarithmic spiral. However, the enlargement ratio of the air flow path is fundamentally important, and the curve may not be limited to the logarithmic spiral and may include a straight line section. In the range from the enlarged start point of the air flow path to 90° therefrom, the preferable range of the enlarged area ratio τ against the diameter D of the cross flow fan will be analyzed.

[0044] A casing enlargement curve can be set at a preferable range with the configuration of the fan of Embodiment 2 according to the invention. Hence, loss caused by the air flow, which has been discharged from the blades of the cross flow fan, impinging the wall of the casing can be averted, and the momentum of the fluid transferred by the cross flow fan is not lost.

The fan performance is accordingly improved and, as a result, the input energy can be suppressed, reducing noise and vibration. Although in Embodiment 2 of the invention, description has been made with respect to an air-conditioning apparatus provided with a fan, the same effect will be present with a fan with no heat exchanger or a filter.

25 List of Reference Signs

[0045]

1	housing
30 1a	front panel
1b	rear panel
1c	upper panel
1d	bottom panel
1e	left side panel
35 1f	right side panel
2	cross flow fan
3	heat exchanger
4	inlet port
5	grille
40 6	filter
7	casing
8	outlet port
9	stabilizer
10	blade
45 10a	blade outer side
10b	blade inner side

Claims

- 50
1. A fan comprising: a housing including an inlet port and an outlet port; a cross flow fan disposed in the housing; a casing arranged on a back side of the cross flow fan, the casing constituting a part of the outlet port; and a stabilizer arranged on a front side of the cross flow fan, the stabilizer opposing the casing and constituting a part of the outlet port, wherein when A is a maximum inlet width of the inlet port in
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a direction substantially orthogonal to a rotation axis of the cross flow fan, D is a diameter of the cross flow fan, and β is an outer peripheral blade inflow angle,

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$$\beta = (A / D) \gamma \text{ (radian),}$$

in which $A / D \leq 2$ and $0.4 \geq \gamma \geq 0.3$ is defined.

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2. A fan comprising: a housing including an inlet port and an outlet port; a cross flow fan disposed in the housing; a casing arranged on a back side of the cross flow fan, the casing constituting a part of the outlet port; and a stabilizer arranged on a front side of the cross flow fan, the stabilizer opposing the casing and constituting a part of the outlet port, wherein an enlarged area ratio is defined as

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$$1.416 \geq \tau \geq 1.466,$$

where the enlarged area ratio is a ratio of dividing an enlarged air flow path area, which is an area surrounded by a curved line made by the enlarged air flow path of the casing; a line segment connecting a rotation center of the cross flow fan to a starting portion of the enlarged air flow path, the line segment having a length of r_0 ; and a straight line that is, with respect to the rotation center of the cross flow fan, 90° from the line segment, by a sector area of 90° that has a radius of r_0 .

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3. The fan of claim 2 comprising: the housing including the inlet port and the outlet port; the cross flow fan disposed in the housing; the casing arranged on the back side of the cross flow fan, the casing constituting a part of the outlet port; and the stabilizer arranged on the front side of the cross flow fan, the stabilizer opposing the casing and constituting a part of the outlet port, wherein when A is a maximum inlet width of the inlet port in a direction substantially orthogonal to a rotation axis of the cross flow fan, D is a diameter of the cross flow fan, and β is an outer peripheral blade inflow angle,

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$$\beta = (A / D) \times \gamma \text{ (radian),}$$

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in which $A / D \leq 2$ and $0.4 \geq \gamma \geq 0.3$ is defined.

4. An air-conditioning apparatus provided with the fan of any one of claims 1 to 3.

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FIG. 1

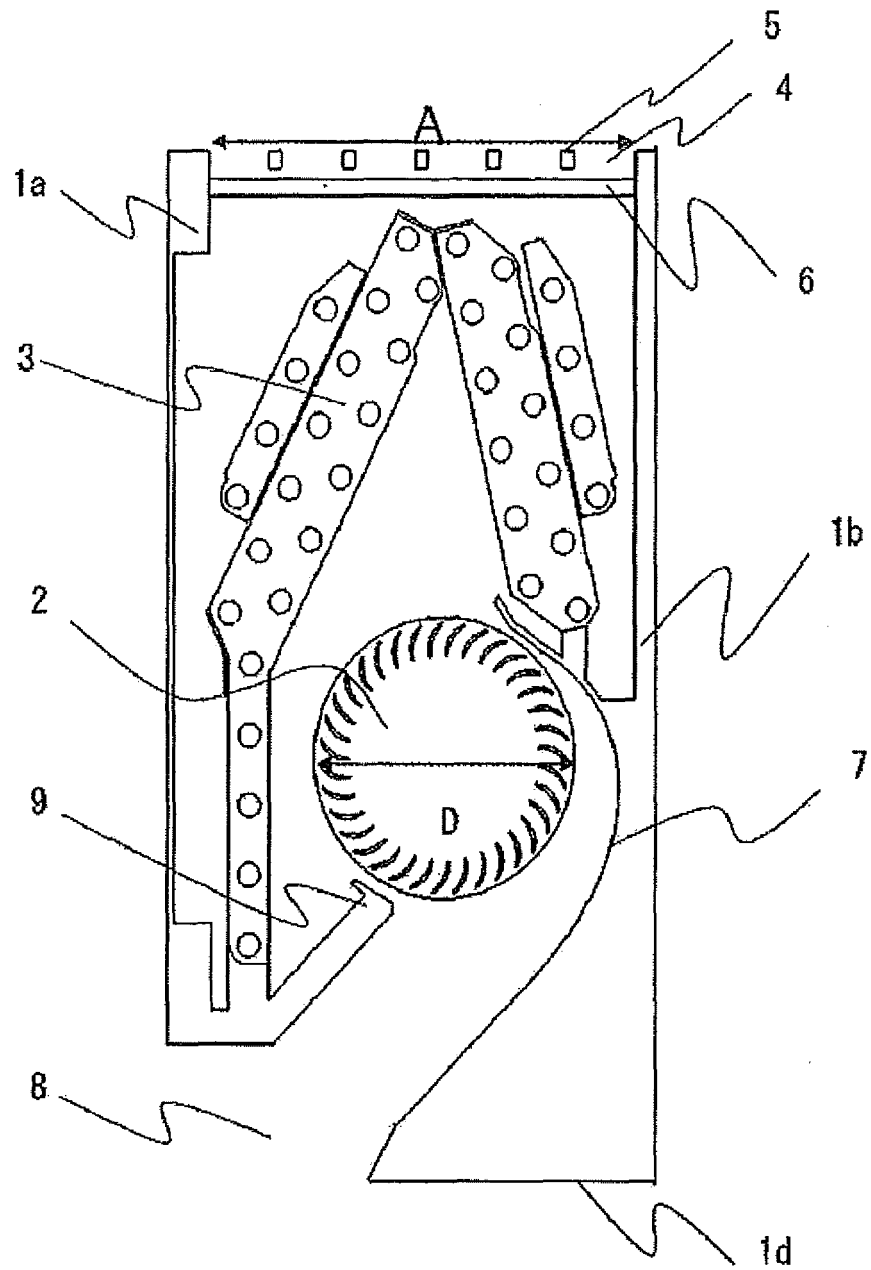


FIG. 2

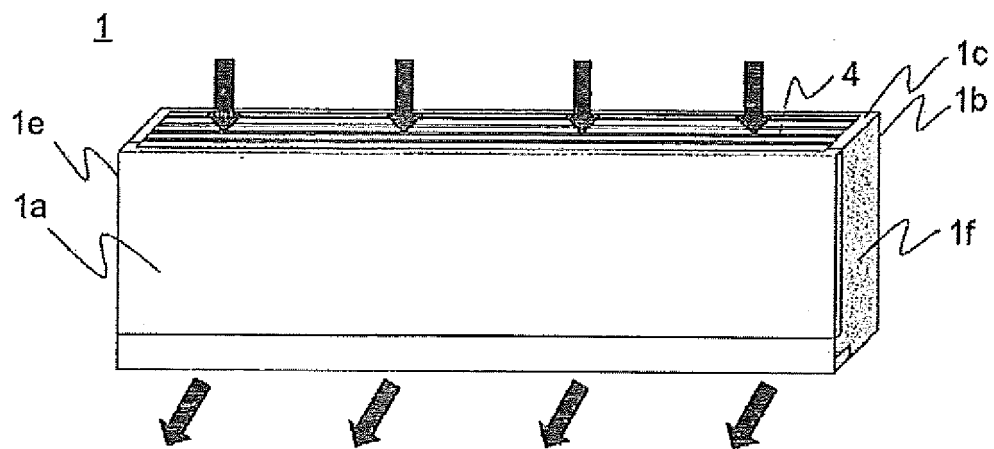


FIG. 3

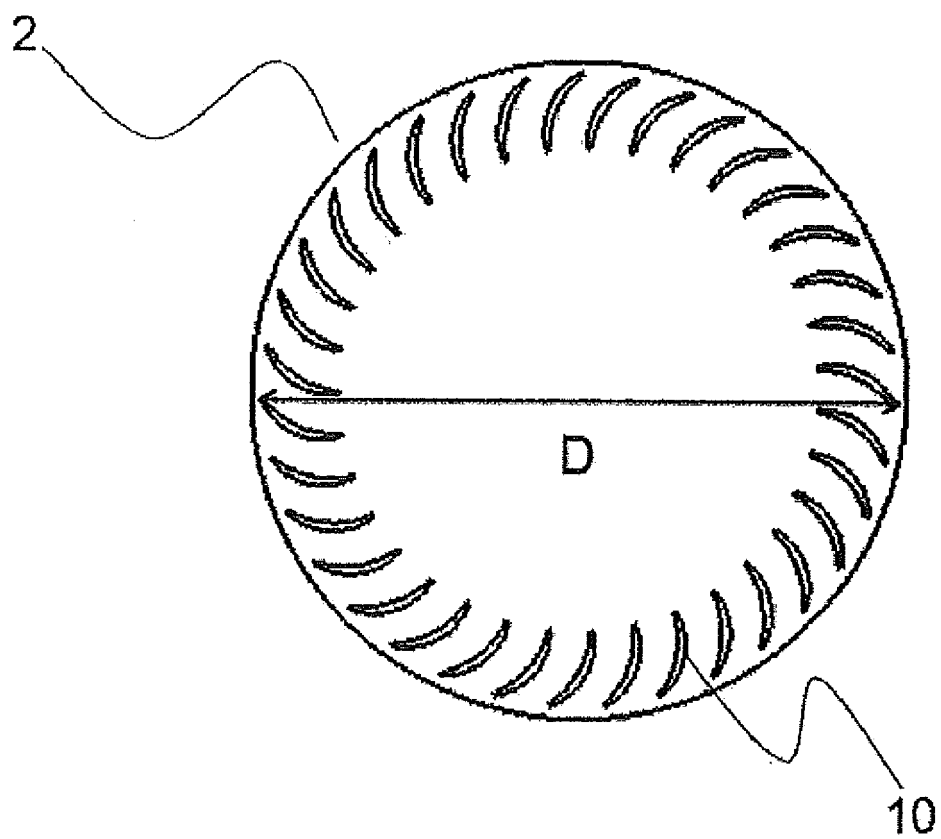


FIG. 4

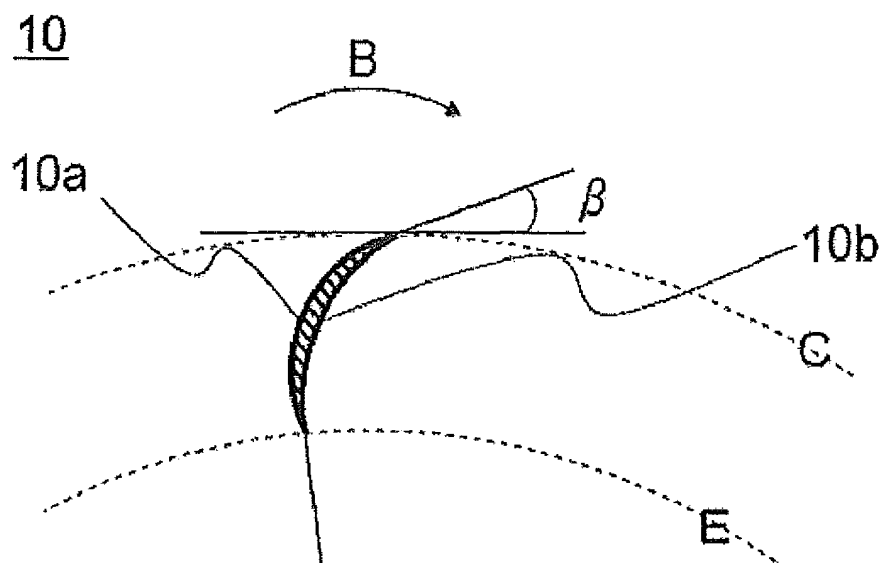


FIG. 5

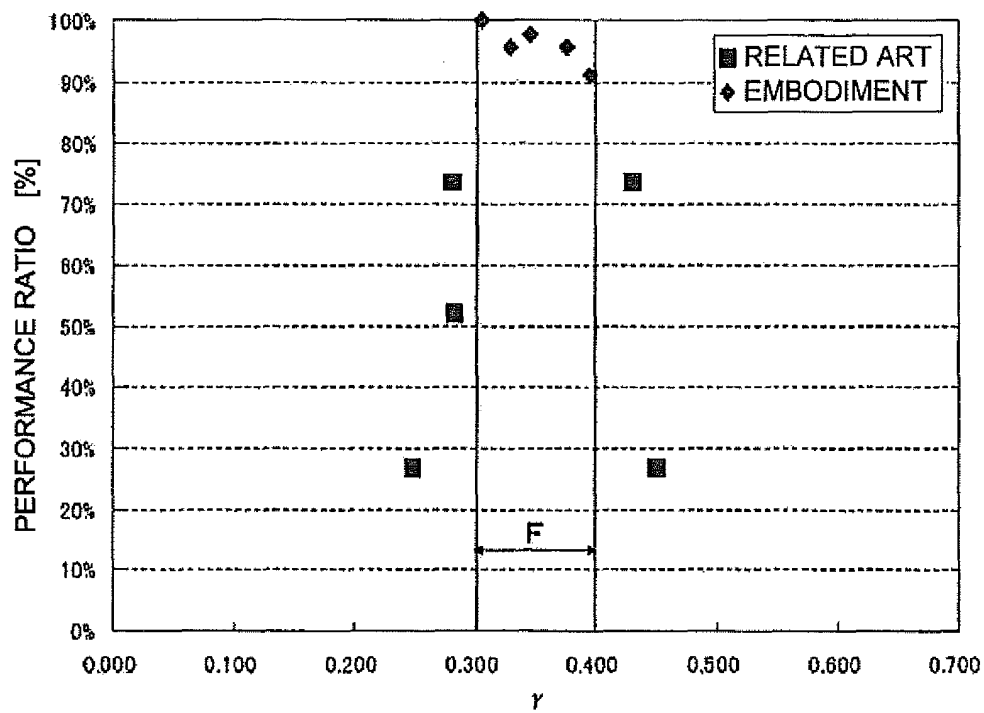


FIG. 6

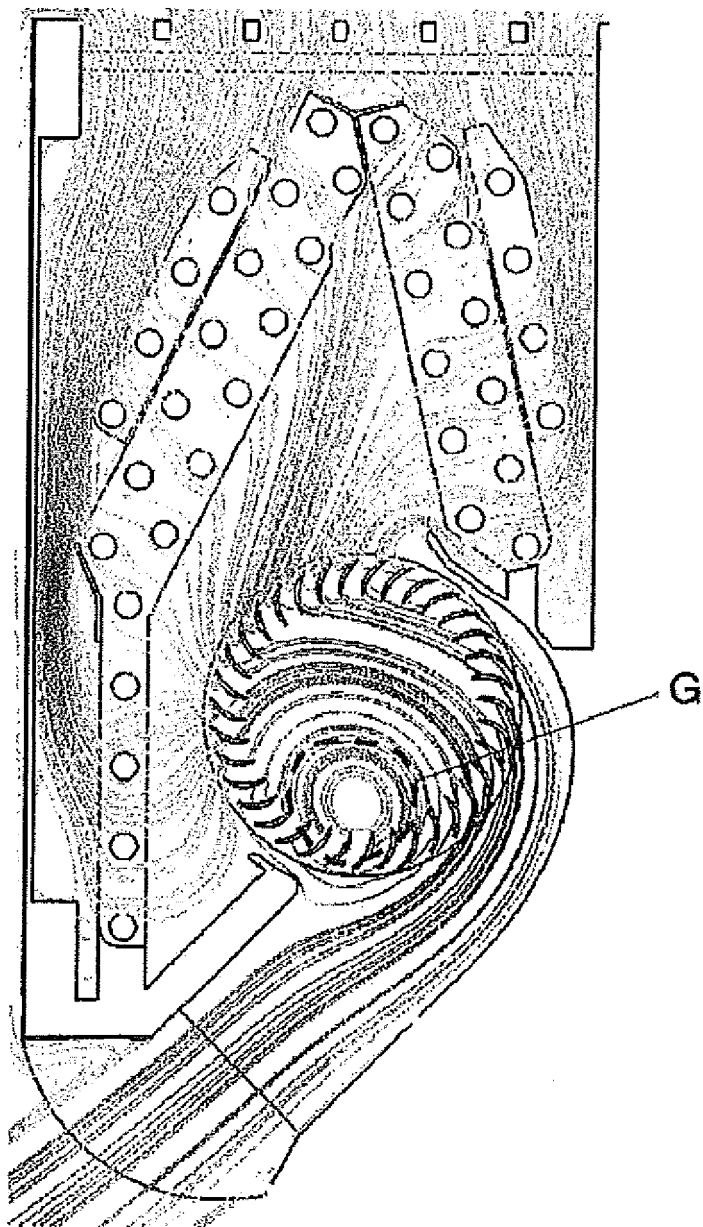


FIG. 7

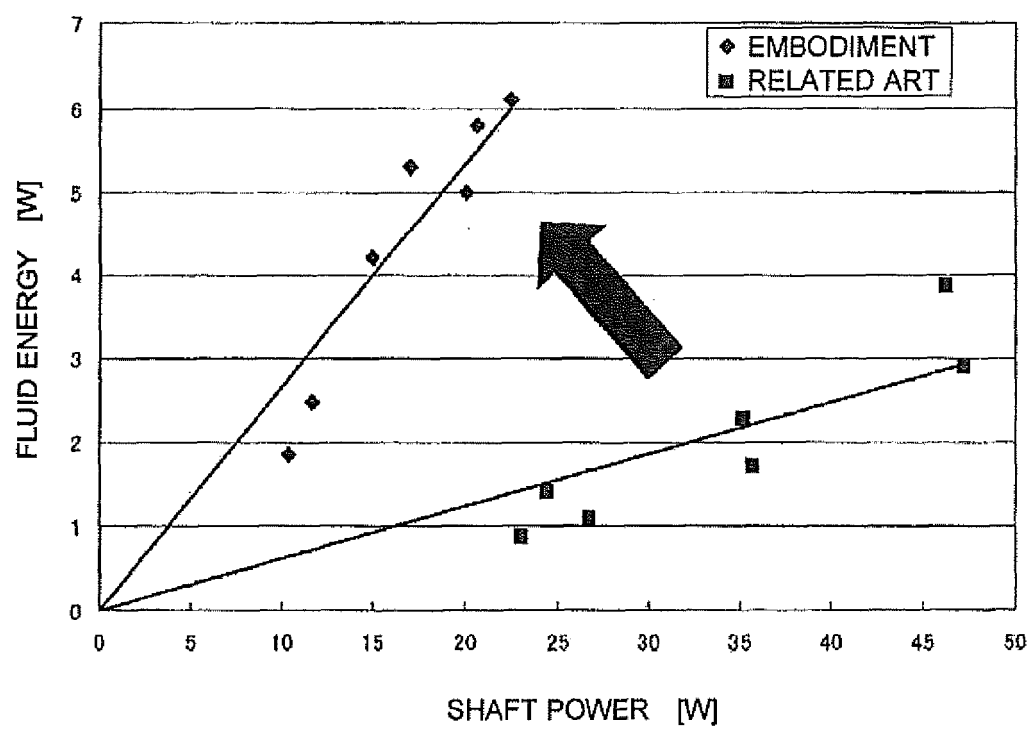


FIG. 8

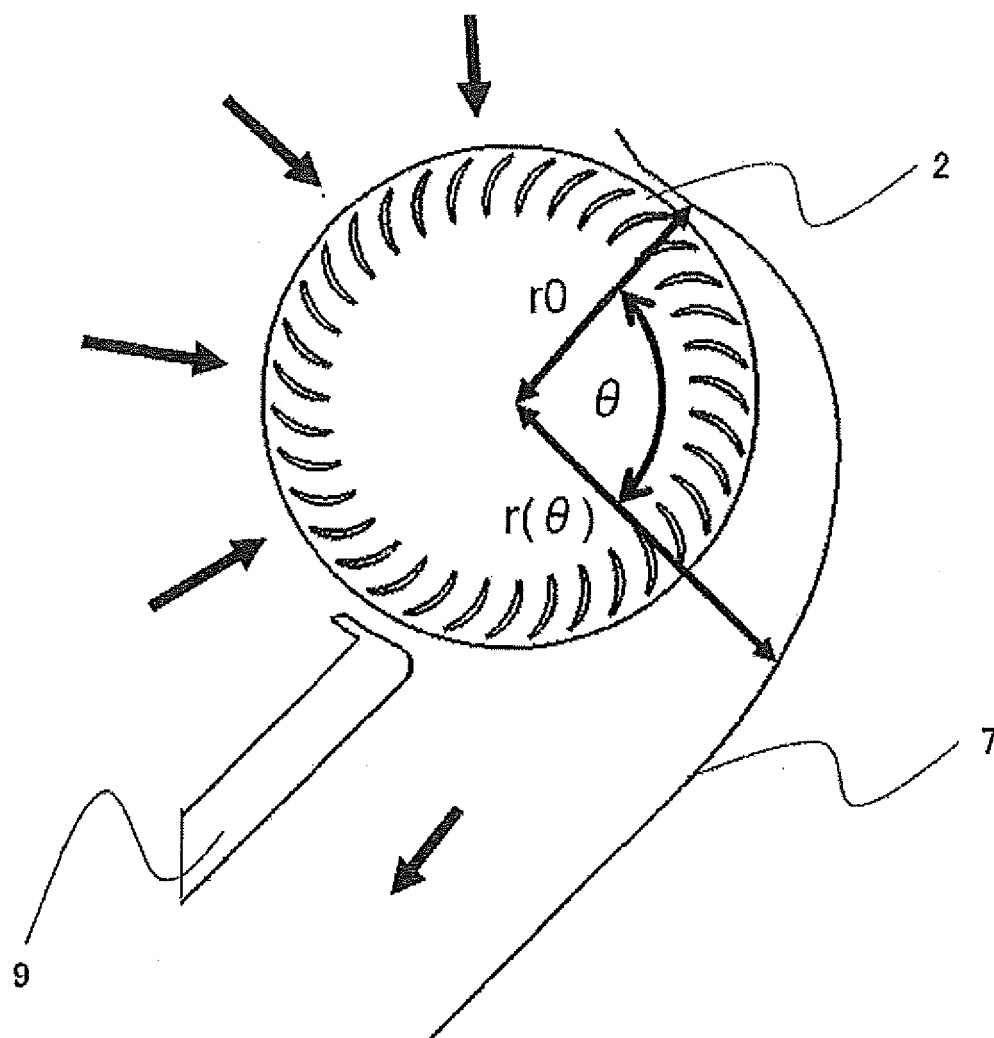


FIG. 9

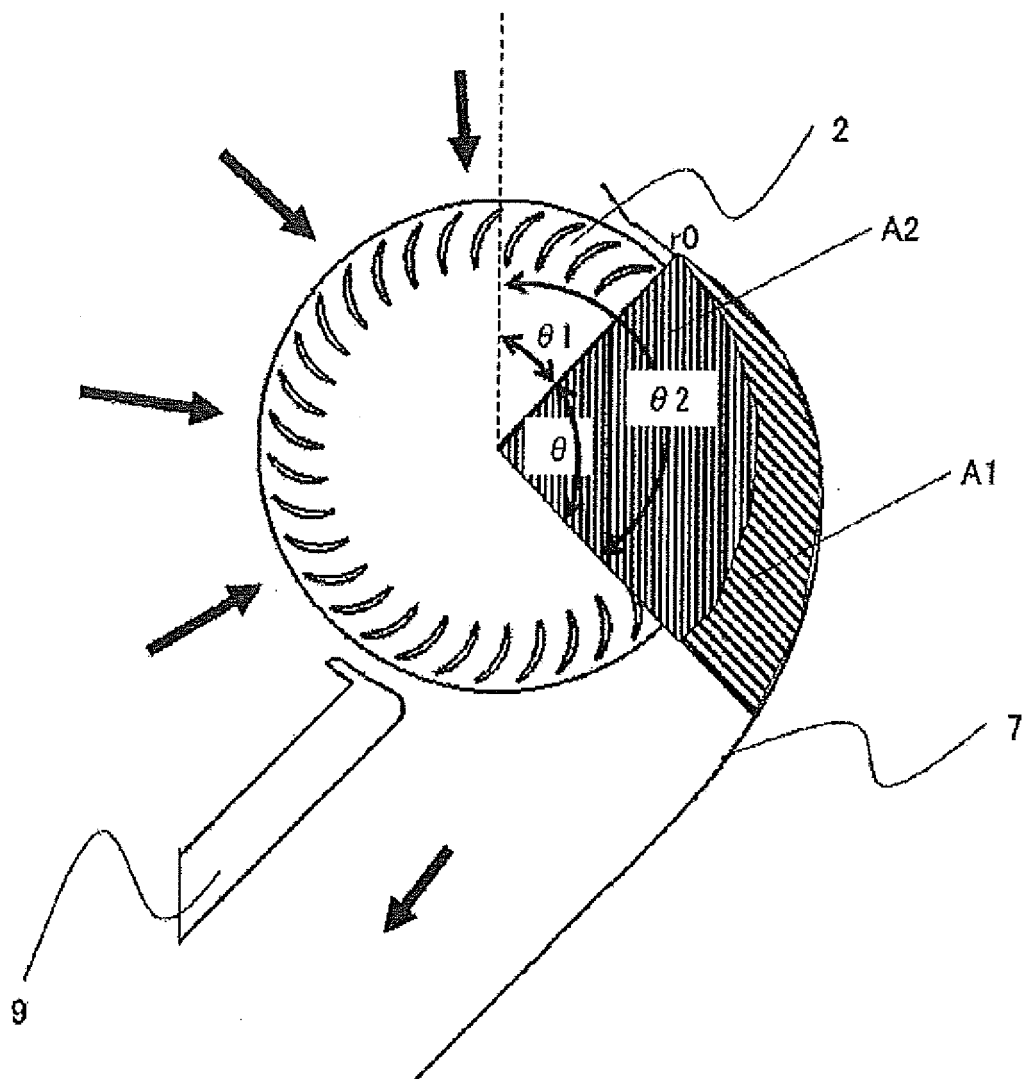


FIG. 10

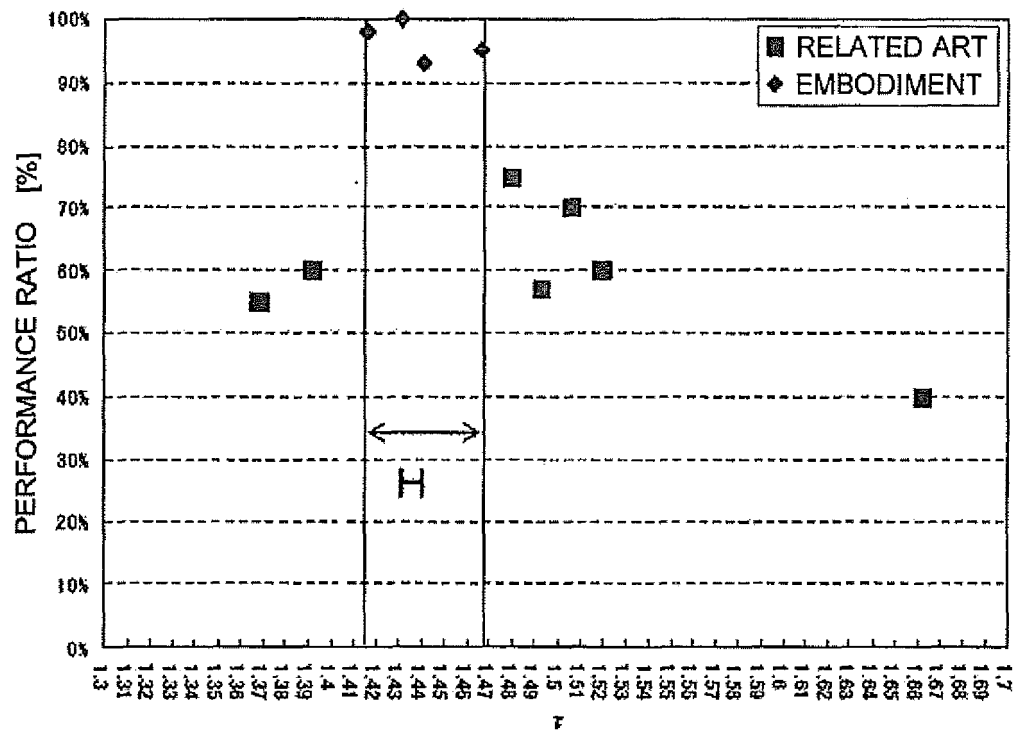


FIG. 11

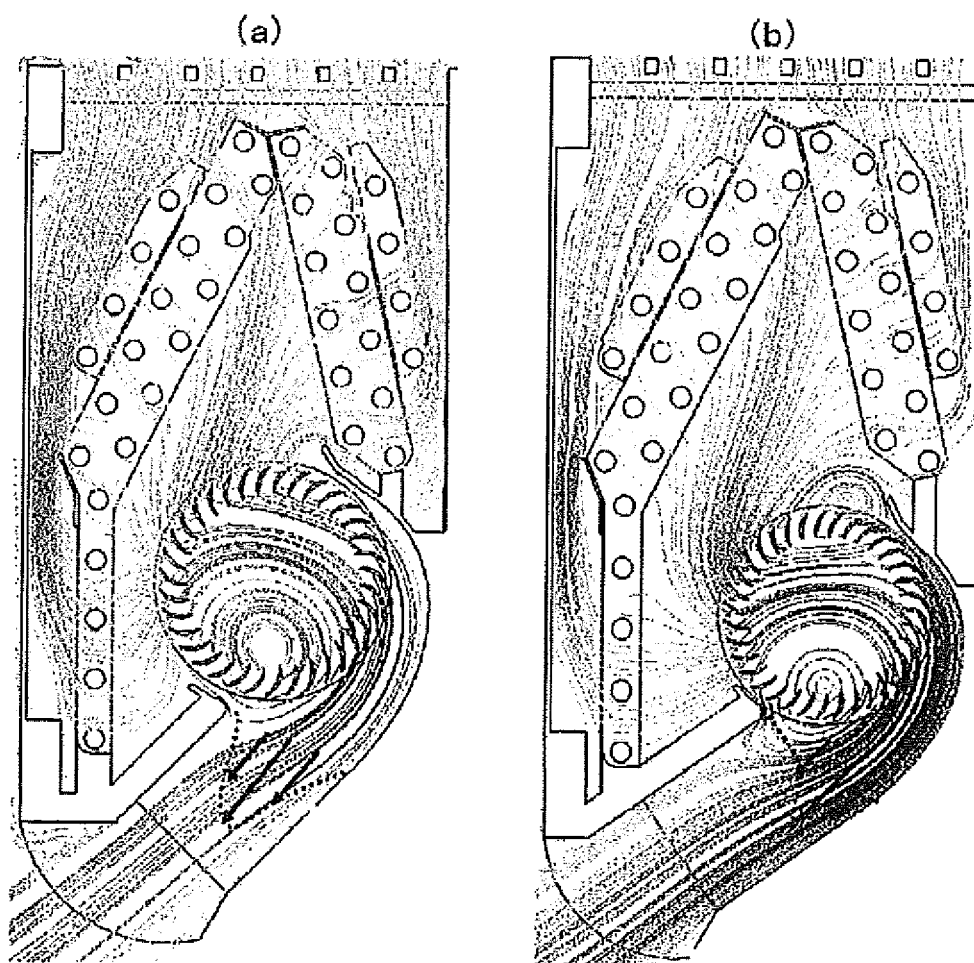
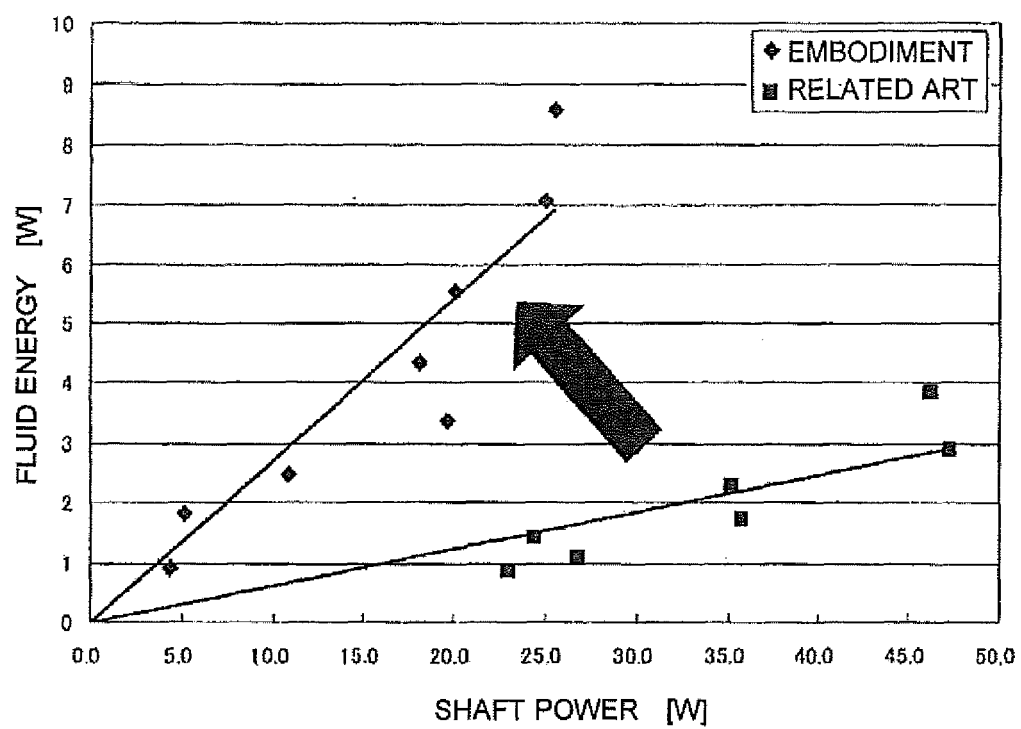


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/004088

A. CLASSIFICATION OF SUBJECT MATTER

F24F1/00 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24F1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 59-93130 A (Tokyo Sanyo Electric Co., Ltd.), 29 May 1984 (29.05.1984), entire text; all drawings (Family: none)	1-4
A	JP 5-280760 A (Mitsubishi Heavy Industries, Ltd.), 26 October 1993 (26.10.1993), entire text; all drawings (Family: none)	1-4
A	JP 2007-40543 A (Fujitsu General Ltd.), 15 February 2007 (15.02.2007), entire text; all drawings (Family: none)	1-4

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

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"&" document member of the same patent family

Date of the actual completion of the international search
19 November, 2009 (19.11.09)Date of mailing of the international search report
01 December, 2009 (01.12.09)Name and mailing address of the ISA/
Japanese Patent Office

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 6323294 A [0012]
- JP 2004150789 A [0012]