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(54) **Axial-flow fan**

Axiallüfter

Ventilateur axial

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GB-A- 401 625 US-B1- 6 447 251

EP 1 422 425 B1

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an axial-flow fan, which reduces the difference of pressure between a positive pressure side and a negative pressure side at the blade tip of each of blades, thereby preventing the occurrence of a vortex stream and subsequently reducing noise. In particular the present invention relates to an axial-flow fan as specified in the preamble of claim 1. Such a fan is known from EP-A-0 992 693.

Description of the Related Art

[0002] Generally, an axial-flow fan is an apparatus which is connected to a rotary shaft of a motor, and sucks a fluid at its one side and then discharges the fluid at its opposite side in the centrifugal direction when a driving force of the motor is transmitted to the axial-flow fan via the rotary shaft. The axial-flow fan has been widely applied in electrical appliances such as an air conditioner, a refrigerator, a microwave oven, etc.

[0003] More specifically, as shown in Figs. 1 and 2, the conventional axial-flow fan comprises a hub 2 connected to a rotary shaft (not shown) of a motor, and a plurality of blades 4 positioned on the outer circumference of the hub 2 and spaced from each other by a designated interval, thereby blowing air in the centrifugal direction.

[0004] When the axial-flow fan is rotated, the air is propelled from the rear side of the axial-flow fan to the front side of the axial-flow fan. Since the air flows along the front side of the blade 4, relatively higher pressure of the air is applied to the front side of the blade 4, and relatively lower pressure of the air is applied to the rear side of the blade 4. Herein, the front and rear sides of the blade 4 are referred to as a positive pressure side 4a and a negative pressure side 4b, respectively.

[0005] When the aforementioned axial-flow fan is operated so that the blades 4 are rotated, air flows along the blades 4, thereby causing the difference of pressure between the positive pressure sides 4a and the negative pressure sides 4b. When the blades 4 are rotated, the air flows in the radial direction of the blade 4 by means of the centrifugal force.

[0006] Here, a vortex stream occurs at a tip blade 4c, i.e., a circumferential surface of the blade 4. Subsequently, there occurs BVI (Blade Vortex Interaction) in that the blade 4 collides with the vortex stream generated by the earlier blade 4 based on the rotational direction of the axial-flow fan, thus generating noise.

[0007] Further, since the difference of pressure between the positive pressure side 4a and the negative pressure side 4b at the blade tip 4c is great, when air flowing from the positive pressure side 4a of the blade 4

to the negative pressure side 4b of the blade 4, the air is rapidly restored to its static pressure, thereby generating a vortex and generating noise by the collision of the vortex with peripheral structures.

5 **[0008]** Accordingly, attempts for reducing the noise generated by the BVI and the restoration of air to the static pressure h have been recently made.

[0009] More specifically, since the BVI and the sudden restoration to the static pressure of air flowing over the blade 4 are caused by the difference of pressure between the positive pressure side 4a and the negative pressure side 4b at the blade tip 4c, in order to reduce the difference of pressure between the positive pressure side 4a and the negative pressure side 4b at the blade tip 4c, there has been required an axial-flow fan which reduces the amount of airflow blown toward the positive pressure side 4a at the blade tip 4c or allows air to effectively flow between the positive pressure side 4a and the negative pressure side 4b at the blade tip 4c.

SUMMARY OF THE INVENTION

[0010] Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide an axial-flow fan comprising blades having improved shapes so as to reduce the difference of pressure between positive pressure sides and negative pressure sides at tips of the blades when the fan is operated, thereby reducing the occurrence of a vortex stream.

25 **[0011]** In accordance with the present invention, the above and other objects can be accomplished by the provision of an axial-flow fan as defined in claim 1.

[0012] Preferably, each blade may have a designated rake angle.

35 **[0013]** Further, preferably, the protuberance may be located at a part of the section from a position of "0.3" to a position of "1" of a distance from a blade hub to a blade tip.

40 **[0014]** Otherwise, preferably, the protuberance may be located throughout the section from a position of "0.3" to a position of "1" of a distance from a blade hub to a blade tip.

45 **[0015]** Moreover, preferably, the protuberance may be formed on the positive pressure side so as to have a convex-shaped structure when viewed from the positive pressure side.

[0016] |

50 **[0017]** Further, preferably, the peak of the protuberance may be positioned close to the blade tip, the peak of the protuberance may be located between a position of "0.7" and a position of "0.8" of the distance from the blade hub to the blade tip.

55 **[0018]** Moreover, preferably, leading and trailing edges of the protuberance may be located on a line obtained by connecting a blade hub and a blade tip.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective view of a conventional axial-flow fan;

Fig. 2 is a partially broken-away perspective view of the conventional axial-flow fan;

Fig. 3 is a perspective view of an axial-flow fan in accordance with the present invention;

Fig. 4 is a partially broken-away perspective view of the axial-flow fan in accordance with the present invention;

Fig. 5 is a cross-sectional view of a blade of the axial-flow fan in accordance with the present invention;

Fig. 6 is a graph showing a variation in an amount of airflow relative to a variation in the number of rotations of the conventional axial-flow fan and the axial-flow fan of the present invention;

Fig. 7 is a graph showing a variation in power consumption relative to a variation in the number of rotations of the conventional axial-flow fan and the axial-flow fan of the present invention;

Fig. 8 is a graph showing a variation in noise generation relative to a variation in the number of rotations of the conventional axial-flow fan and the axial-flow fan of the present invention; and

Fig. 9 is a graph showing a variation in noise generation relative to a variation in frequency of the conventional axial-flow fan and the axial-flow fan of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] Now, a preferred embodiment of the present invention will be described in detail with reference to the annexed drawings.

[0021] As shown in Figs. 3 to 5, an axial-flow fan of the present invention comprises a hub 52, a plurality of blades 54, and protuberances 56. Each blade 54 is formed with one of the protuberances 56. The hub 52 is formed as a cylinder with the uniform diameter at a front side 52a and a rear side 52b, and guides air to centrifugally flow along the circumference of the hub 52. A rotary shaft of a motor is fit into the center of the hub 52. The blades 54 are positioned on the outer circumference of the hub 52 and circumferentially spaced from each other by a designated interval so as to allow air to flow in the centrifugal direction. The protuberance 56 is formed on a designated part of each of the blades 54 so as to suppress a vortex of air flowing along the blades 54.

[0022] Based on the rotational direction of the fan, a front edge of the blade 54 is referred to as a leading edge 54a, and a rear edge of the blade 54 is referred to as a trailing edge 54b. A circumferential ridge obtained by in-

terconnecting the tips of the leading edge 54a and the trailing edge 54b is referred to as a blade tip 54c.

[0023] The blade tip 54c from the leading edge 54a to the trailing edge 54b has a predetermined curvature so that the leading edge 54a is located on the front side 52a of the hub 52 and the trailing edge 54b is located on the rear side 52b of the hub 52.

[0024] Accordingly, when the axial-flow fan is rotated, air is introduced into the fan via the leading edge 54a, flows along the blade 54, and then is centrifugally discharged from the fan via the front side of the blade 54.

[0025] Here, the front side of the blade 54 to which high pressure of the introduced air is applied is referred to as a positive pressure side 54d, and the rear side of the blade 54 is referred to as a negative pressure side 54e.

[0026] The above-described blade 54 has a designated rake angle (θ).

[0027] The rake angle (θ) of the blade 54 is an angle at which the blade 54 is tilted toward the rear side 52b of the hub 52. More specifically, the rake angle (θ) of the blade 54 is an angle between a Y-axis passing through the center of the hub 52 and a cross-section of the blade 54 taken along a line obtained by connecting a blade hub 54f and the blade tip 54c.

[0028] Here, the line obtained by connecting the blade hub 54f and the blade tip 54c is referred to as a rake base line (L).

[0029] The protuberance 56 is curved so as to be protruded from the blade tip 54c toward the positive pressure side 54d. As shown in Fig. 5, in case that the distance from the blade hub 54f to the blade tip 54c is predetermined as "1", the protuberance 56 is located throughout the section from the position of "0.3" to the position of "1".

[0030] The protuberance 56 includes a front portion 56a and a rear portion 56b. The protuberance 56 is centered on the peak (P) of the protuberance 56, i.e., the most protruding portion of the protuberance 56, such that the front portion 56a is located close to the blade hub 54f and tilted upward in the radial direction of the blade 54 toward on the peak (P) of the protuberance 56, and the rear portion 56b is located close to the blade tip 54c and tilted downward in the radial direction of the blade 54 from the peak (P) of the protuberance 56.

[0031] Here, the peak (P) is positioned closer to the blade tip 54c than to the blade hub 54f. That is, the peak (P) is located between the position of "0.7" and the position of "0.8" of the distance from the blade hub 54f to the blade tip 54c, and has from the rake base line (L) a height of approximately 5~10% of the distance between the blade hub 54f and the blade tip 54c.

[0032] The rear portion 56b of the protuberance 56 is formed throughout a radial distance shorter than that of the front portion 56a connected to the rear portion 56b. Accordingly, the rear portion 56b has a steeper degree of slope than that of the front portion 56a, thereby allowing air passing through the peak (P) along the blade 54 to effectively flow at the blade tip 54c.

[0033] A leading edge 56L of the protuberance 56 is located at the position of "0.3" of the distance from the blade hub 54f to the blade tip 54c, and a trailing edge 56T of the protuberance 56 is located at the blade tip 54c. The leading and trailing edges 56L and 56T of the protuberance 56 are positioned on the rake base line (L).

[0034] On the other hand, the protuberance 56 may be located at a part of the section from the position of "0.3" to the position of "1" of the distance from the blade hub 54f and the blade tip 54c.

[0035] The curve of the protuberance 56 is expressed by a secondary function or an (n)th function (n = a natural number) so that the cross-section of the protuberance 56 taken along the line connecting the blade hub 54f and the blade tip 54c is convex-shaped when viewed from the positive pressure side 54d.

[0036] Hereinafter, the operation of the above-described axial-flow fan of the present invention is described.

[0037] First, when the motor is driven, the axial-flow fan fixed to the rotary shaft of the motor is rotated. Air is introduced into the axial-flow fan via the front side 52a of the hub 52, and then centrifugally discharged from the axial-flow fan via the rear side 52b of the hub 52. Here, the air circumferentially flows from the leading edges 54a of the blades 54 to the trailing edges 54b of the blades 54, and simultaneously, radially flows from the blade hubs 54f to the blade tips 54c of the blades 54.

[0038] The introduced air is divided into two portions by the leading edge 54a of the blade 54, and the divided two portions of the air are respectively fed to the positive pressure side 54d and the negative pressure side 54e of the blade in the circumferential direction of the blade. High pressure of the air is applied to the positive pressure side 54d, and low pressure of the air is applied to the negative pressure side 54e.

[0039] When the axial-flow fan is rotated, the air discharged from the blades 54 by means of the centrifugal force flows along the radial direction of the positive pressure side 54d and is guided by the protuberance 56 on the positive pressure side 54d.

[0040] More specifically, the air flowing between the blade hub 54f and the peak (P) of the protuberance 56 is first introduced along the front end of the leading edge 54a, and then discharged from the front end the trailing edge 54b along the front portion 56a of the protuberance 56 of the positive pressure side 54d and simultaneously flows along the front portion 56a of the protuberance 56 in the radial direction of the blade 54 by the centrifugal force. Since the front portion 56a of the protuberance 56 is tilted upward in the radial direction of the blade 54, the amount of airflow blowing toward the blade tip 54c along the positive pressure side 54d is reduced. Accordingly, the pressure of airflow on the positive pressure side 54d at the blade tip 54c is lowered.

[0041] On the other hand, the air flowing between the peak (P) of the protuberance 56 and the blade tip 54c is first introduced along the rear end of the leading edge

54a, and then discharged from the rear end of the trailing edge 54b along the rear portion 56b of the protuberance 56 of the positive pressure side 54d and simultaneously flows along the rear portion 56b of the protuberance 56 in the radial direction of the blade 54 by the centrifugal force. Since the rear portion 56b of the protuberance 56 is tilted downward in the radial direction of the blade, the air effectively flows between the positive pressure side 54d and the negative pressure side 54e at the blade tip 54c along the rear portion 56b of the protuberance 56.

[0042] As a consequence, it is possible to reduce the amount of airflow blowing from the positive pressure side 54d to the blade tip 54c and to allow the air to effectively flow between the positive pressure side 54d and the negative pressure side 54e at the blade tip 54c, thereby preventing the occurrence of a vortex stream caused by the difference of pressure between the positive pressure side 54d and the negative pressure side 54e, and reducing noise generated by the BVI when the blade 54 collides with the vortex stream of the earlier blade 54.

[0043] Further, the pressure of an airflow applied to the positive pressure side 54d at the blade tip 54c is relatively lowered, and the restoration to the static pressure of air flowing from the positive pressure side 54d to the negative pressure side 54e is slowly performed, thereby reducing noise caused by the collision of the air with the peripheral structures.

[0044] With reference to Figs. 6 to 8, the axial-flow fan of the present invention comprising the protuberances 56 formed at designated positions of the blades 54 has the same performance as that of the conventional axial-flow fan in terms of the amount of airflow and the power consumption relative to the number of rotations of the axial-flow fan. On the other hand, compared to the conventional axial-flow fan, the axial-flow fan of the present invention generates reduced noise relative to the number of rotations of the axial-flow fan.

[0045] With reference to Fig. 9, compared to the conventional axial-flow fan, the axial-flow fan of the present invention generates reduced isolated noise caused by the collision of the vortex occurring at the blade tip 54c with peripheral structures, relative to a variation in frequency.

[0046] That is, compared to the conventional axial-flow fan, the axial-flow fan of the present invention having the above-described anti-noise structure improves the noise reduction ratio.

[0047] As apparent from the above description, the axial-flow fan of the present invention has several advantages, as follows.

[0048] First, since the protuberances formed on the positive pressure sides of the blades prevent air introduced at the front ends of the leading edges from flowing toward the blade tips, the axial-flow fan of the present invention reduces the amount and the pressure of airflow flowing along the positive pressure sides at the blade tips, thereby reducing the difference of pressure between the positive pressure sides and the negative pressure

sides, diminishing the occurrence of a vortex stream and the noise generated thereby.

[0049] Second, since the protuberances formed on the positive pressure sides of the blades allow air introduced at the rear ends of the leading edges to effectively flow toward the blade tips, the axial-flow fan of the present invention lowers the pressure of airflow applied on the positive pressure sides at the blade tips, thereby slowing down the restoration to the static pressure of air flowing from the positive pressure sides to the negative pressure sides and reducing noise caused by the collision of the air with the peripheral structures.

[0050] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, if without departing from the scope of the invention as disclosed in the accompanying claims.

Claims

1. An axial-flow fan comprising a hub and a plurality of blades (54) located on an outer circumference of the hub (52) so as to axially blow air, wherein each blade (54) includes a positive pressure side to which high pressure of the air is applied, a negative pressure side to which low pressure of the air is applied, and a protuberance (56) formed on the positive pressure side, such that a front portion (56a) of the protuberance (56) located close to the blade hub (54f) is tilted upward in the radial direction of the blade (54) toward the most protruding peak (P) of the protuberance (56), a rear portion (56b) of the protuberance (56) located close to the blade tip (54c) is tilted downward in the radial direction of the blade (54) from the most protruding peak (P) of the protuberance (56),
characterized in that
the rear portion (56b) of the protuberance (56) has a steeper degree of slope than that of the front portion (56a) of the protuberance (56).

2. The axial-flow fan as set forth in claim 1, wherein each blade (54) has a designated rake angle.
3. The axial-flow fan as set forth in claim 1, wherein the protuberance (56) is located at a part of the section from a position of "0.3" to a position of "1" of a distance from the blade hub (54f) to the blade tip (54c).
4. The axial-flow fan as set forth in claim 3, wherein the protuberance (56) is located close to the blade tip (54c).
5. The axial-flow fan as set forth in claim 1,

wherein the protuberance (56) is located throughout the section from a position of "0.3" to a position of "1" of a distance from the blade hub (54f) to the blade tip (54c).

6. The axial-flow fan as set forth in claim 3 or 5, wherein the protuberance (56) is formed on the positive pressure side so as to have a convex-shaped structure when viewed from the positive pressure side.
7. The axial-flow fan as set forth in claim 1, wherein the peak (P) of the protuberance (56) is positioned close to the blade tip (54c).
8. The axial-flow fan as set forth in claim 7, wherein the peak (P) of the protuberance (56) is located between a position of "0.7" and a position of "0.8" of the distance from the blade hub (54f) to the blade tip (54c).
9. The axial-flow fan as set forth in claim 1, wherein leading and trailing edges (54a, 54b) of the protuberance (56) are each located on a line obtained by connecting the blade hub (54f) and the blade tip (54c).

Patentansprüche

1. Axialstromlüfter, mit einer Nabe und mehreren Schaufeln (54), die sich an einem äußeren Umfang der Nabe (52) befinden, um Luft axial zu blasen, wobei jede Schaufel (54) eine Überdruckseite, die mit hohem Luftdruck beaufschlagt wird, eine Unterdruckseite, die mit niedrigem Luftdruck beaufschlagt wird, sowie eine Wölbung (56), die auf der Überdruckseite ausgebildet ist, enthält, so dass ein vorderer Abschnitt (56a) der Wölbung (56), der sich in der Nähe der Schaufelnabe (54f) befindet, in radialer Richtung der Schaufel (56) nach oben zu dem am weitesten vorstehenden Scheitel (P) der Wölbung (56) geneigt ist und ein hinterer Abschnitt (56b) der Wölbung (56), der sich in der Nähe der Schaufelspitze (54c) befindet, in radialer Richtung der Schaufel (54) von dem am weitesten vorstehenden Scheitel (P) der Wölbung (56) nach unten geneigt ist,
dadurch gekennzeichnet, dass
der hintere Abschnitt (56b) der Wölbung (56) einen stärkeren Neigungsgrad hat als der vordere Abschnitt (56a) der Wölbung (56).
2. Axialstromlüfter nach Anspruch 1, wobei jede Schaufel (54) einen bestimmten Steigungswinkel hat.
3. Axialstromlüfter nach Anspruch 1, wobei sich die Wölbung (56) in einem Teil des Ab-

schnitts von einer Position bei "0,3" zu einer Position bei "1" eines Abstandes zwischen der Schaufelnabe (54f) und der Schaufelspitze (54c) befindet.

4. Axialstromlüfter nach Anspruch 3, wobei sich die Wölbung (56) in der Nähe der Schaufelspitze (54c) befindet.
5. Axialstromlüfter nach Anspruch 1, wobei sich die Wölbung (56) in dem gesamten Abschnitt von einer Position bei "0,3" zu einer Position bei "1" eines Abstandes von der Schaufelnabe (54f) zu der Schaufelspitze (54c) befindet.
6. Axialstromlüfter nach Anspruch 3 oder 5, wobei die Wölbung (56) auf der Überdruckseite ausgebildet ist, so dass sie bei Betrachtung von der Überdruckseite eine konvex geformte Struktur besitzt.
7. Axialstromlüfter nach Anspruch 1, wobei der Scheitel (P) der Wölbung (56) in der Nähe der Schaufelspitze (54c) positioniert ist.
8. Axialstromlüfter nach Anspruch 7, wobei sich der Scheitel (P) der Wölbung (56) zwischen einer Position bei "0,7" und einer Position bei "0,8" des Abstandes von der Schaufelnabe (54f) zu der Schaufelspitze (54c) befindet.
9. Axialstromlüfter nach Anspruch 1, wobei sich die Vorderkante und die Hinterkante (54a, 54b) der Wölbung (56) auf einer Linie befinden, die durch Verbinden der Schaufelnabe (54f) mit der Schaufelspitze (54c) erhalten wird.

Revendications

1. Ventilateur à flux axial comprenant un moyeu et une pluralité de pales (54) situées sur une circonférence extérieure du moyeu (52) de manière à souffler de l'air axialement, dans lequel chaque pale (54) inclut un côté à pression positive sur lequel s'applique de l'air sous haute pression, un côté à pression négative sur lequel s'applique de l'air à basse pression, et une protubérance (56) formée sur le côté à pression positive, de telle sorte qu'une portion frontale (56a) de la protubérance (56) située proche du moyeu des pales (54f) est basculée vers le haut dans la direction radiale de la pale (54) vers la pointe (P) de la protubérance (56) qui se projette au maximum, une portion arrière (56b) de la protubérance (56) située proche de l'extrémité (54c) de la pale est basculée vers le bas dans la direction radiale de la pale (54) depuis la pointe (P) de la protubérance (56) qui se projette au maximum, **caractérisé en ce que**

la portion arrière (56b) de la protubérance (56) présente une pente plus raide que celle de la portion avant (56a) de la protubérance.

2. Ventilateur à flux axial selon la revendication 1, dans lequel chaque pale (54) présente un angle de dépouille prédéterminé.
3. Ventilateur à flux axial selon la revendication 1, dans lequel la protubérance (56) est située à une partie de la section depuis une position à "0,3" jusqu'à une position à "1" fois une distance depuis le moyeu des pales (ce 54f) jusqu'à l'extrémité (54c) de la pale.
4. Ventilateur à flux axial selon la revendication 3, dans lequel la protubérance (56) est située à proximité de l'extrémité (54c) de la pale.
5. Ventilateur à flux axial selon la revendication 1, dans lequel la protubérance (56) est située sur toute la section depuis une position à "0,3" jusqu'à une position à "1" fois une distance depuis le moyeu des pales (54f) jusqu'à l'extrémité (54c) de la pale.
6. Ventilateur à flux axial selon la revendication 3 ou 5, dans lequel la protubérance (56) est formée sur le côté à pression positive de manière à présenter une structure en forme convexe lorsqu'on l'observe depuis le côté à pression positive.
7. Ventilateur à flux axial selon la revendication 1, dans lequel la pointe (P) de la protubérance (56) est positionnée à proximité de l'extrémité (54c) de la pale.
8. Ventilateur à flux axial selon la revendication 7, dans lequel la pointe (P) de la protubérance (56) est située entre une position à "0,7" est une position à "0,8" fois la distance depuis le moyeu des pales (54f) jusqu'à l'extrémité (54c) de la pale.
9. Ventilateur à flux axial selon la revendication 1, dans lequel le bord d'attaque et le bord de queue (54a, 54b) de la protubérance (56) sont situés chacun sur une ligne obtenue en raccordant le moyeu des pales (54f) et l'extrémité (54c) de la pale.

FIG. 1(Prior Art)

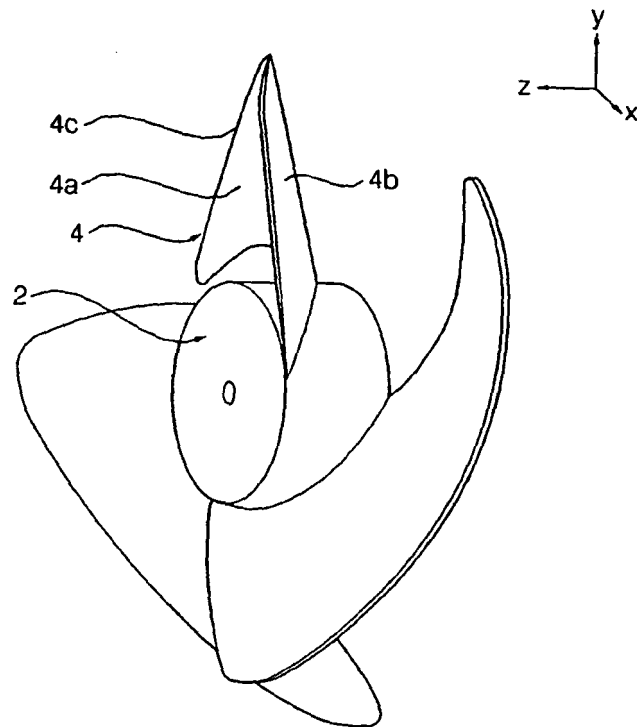


FIG. 2(Prior Art)

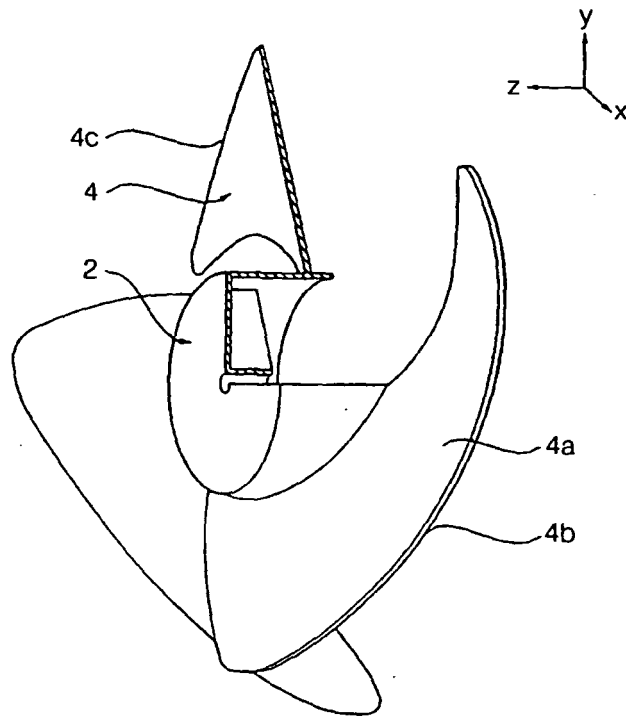


FIG. 3

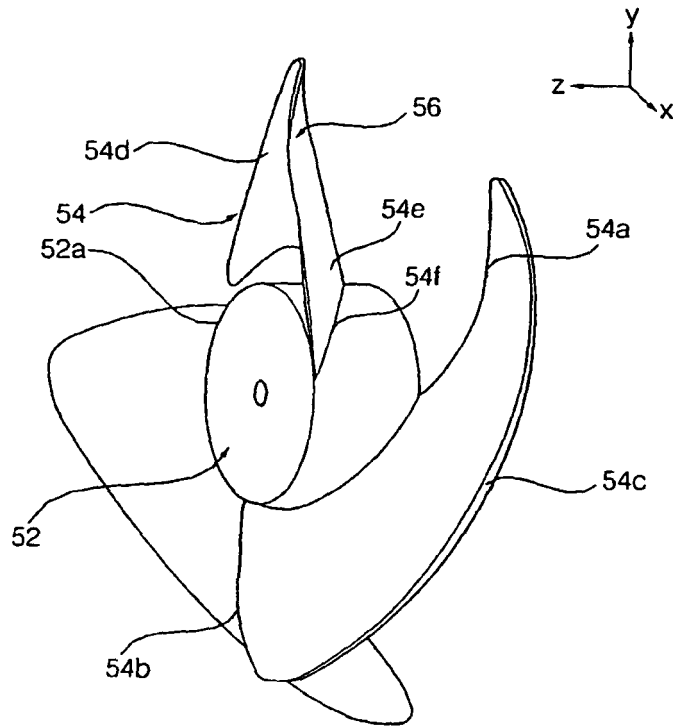


FIG. 4

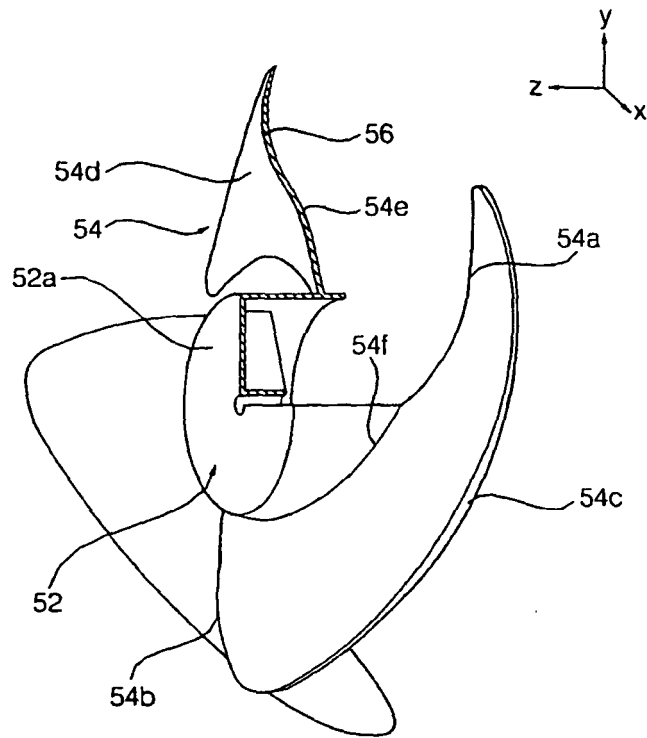


FIG. 5

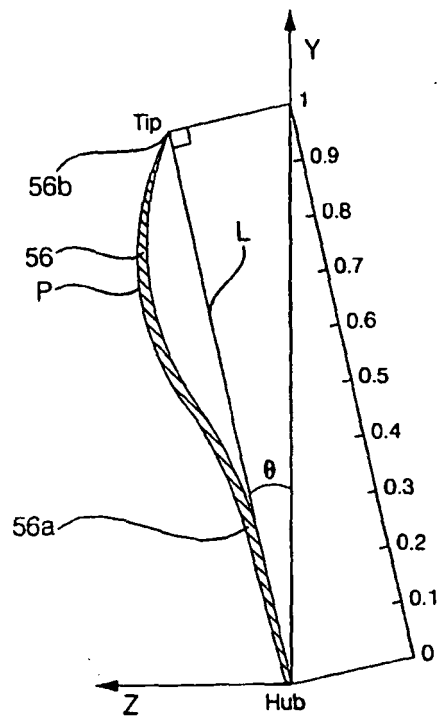


FIG. 6

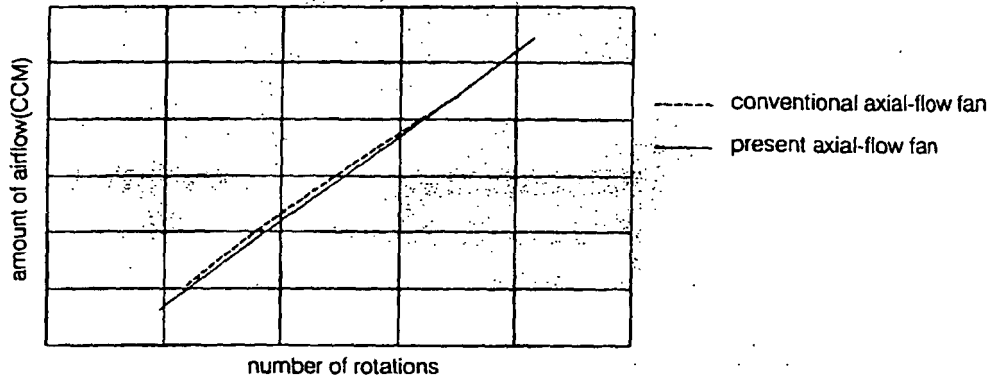


FIG. 7

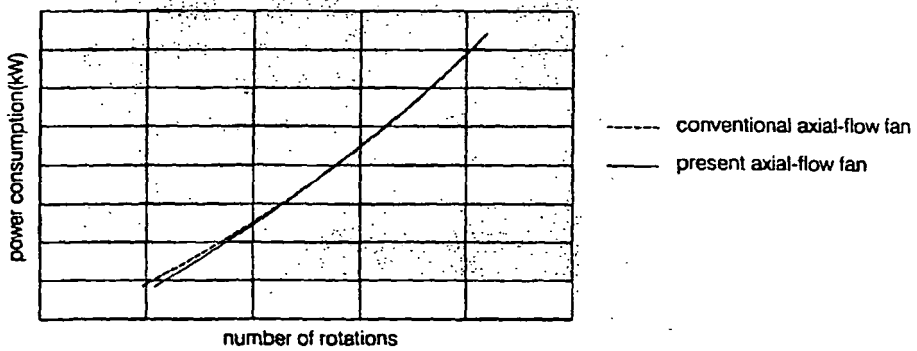


FIG. 8

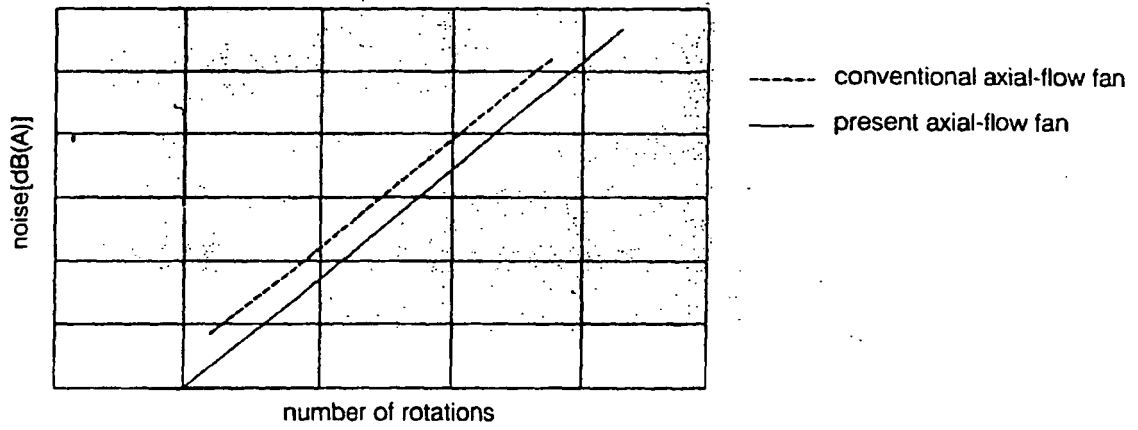
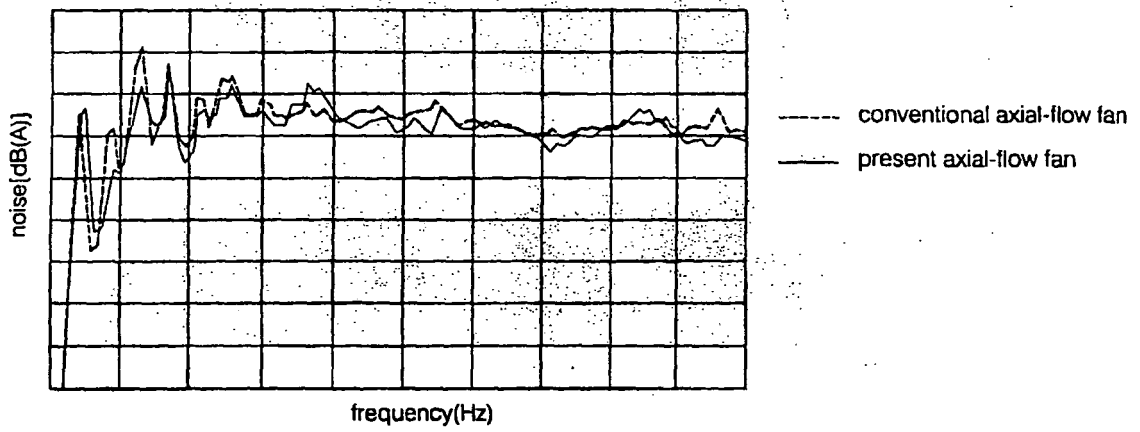


FIG. 9



REFERENCES CITED IN THE DESCRIPTION

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