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(54) **Cross flow fan impeller**

Laufrad für Querstromlüfter

Roue pour une soufflante à courant traversal

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(56) References cited:
DE-A- 2 322 734 **DE-C- 4 421 604**
US-A- 4 538 963 **US-A- 5 266 007**

- **TRANSACTIONS A.S.M.E; JOURNAL OF ENGINEERING FOR BASIC ENGINEERING., vol. 92d, no. 1, March 1970, pages 143-154, XP002030072 R.C. MELLIN: "Controlling the Tonal Characteristics of the AerodynamicNoise Generated by Fan Rotors."**

EP 0 785 362 B1

Description

[0001] The present invention relates to a cross flow fan, especially, to a cross flow fan impeller, where rotational noise of the impeller is reduced in a low frequency band of the noise.

Description of the Related Art

[0002] Referring to Fig. 7, in an internal unit 5 of a known air conditioner, a plurality of outlet nozzles 7 are provided in a lower front panel of a casing 6, a plurality of inlet ports 8 are provided in an upper front panel of the casing 6, and a heat exchanger 9 is provided behind the inlet ports 8 inside of the casing 6. A cross flow fan impeller 4 is located between a back panel of the casing 6 and the heat exchanger 9 inside of the casing 6. Air is led through the inlet ports 8. The temperature of the air is changed by the heat exchanger 9 to cool or warm. The air is sent to the outlet nozzles 7 by rotation of the cross flow fan impeller 4 and the air is thus blown into the interior of a room through the outlet nozzles 7.

[0003] The cross flow fan impeller 4 includes a plurality of division plates 3, which are perpendicular to a rotational axis of the impeller, and a plurality of blades 1 as shown in Fig. 8. The blades 1 are provided at periodic intervals between each pair of division plates 3. As the cross flow fan impeller rotates, the impeller 4 makes a noise, which corresponds to a number of blades. The noise corresponding to the number of blades is called the noise "NZ", hereinafter. To reduce this noise, in another known cross flow fan impeller, for example, the blades 1 are provided aperiodically, that is, provided at random intervals. This type of cross flow fan impeller is disclosed in Japanese Unexamined Patent Publication No. SHO 60-17296.

[0004] DE-A-2 322 734 discloses a cross flow fan with equally spaced blades which have a skew angle.

[0005] US-A-5 266 007 discloses a cross flow fan in accordance with the pre-characterising part of claim 1.

Problems

[0006] Fig. 9 shows a result of frequency analysis of rotational noise of a known cross flow fan impeller, where the blades are provided periodically. Fig. 10 shows a result of frequency analysis of rotational noise of a known cross flow fan impeller where the blades are provided aperiodically, as disclosed in Japanese Unexamined Patent Publication No. SHO 60-17296. In Fig. 10, the noise "NZ" can be reduced in the cross flow fan impeller where the blades are provided aperiodically, as disclosed in Japanese Unexamined Patent Publication No. SHO 60-17296. However, another problem is raised that noise of low frequency, less than 600Hz, is generated as shown in Fig. 10.

[0007] Fig. 10 is a simulation result of frequency analysis of rotational noise of a cross flow fan impeller, where the blades are provided at random intervals based on the following equation.

$$\theta_k = \theta_k 0 + d\theta \times (\,\mathrm{rnd}(\delta) - \delta/2) \tag{1}$$

where,

- θ_k: the locating angle of the k-th blade
- $\theta_k 0$: the locating angle of the k-th blade if the blades were provided at equal intervals
- $d\theta$: the angle between each pair of adjacent blades if the blades were provided at equal intervals
- rnd(): random number generation function
- δ: a distortion coefficient
- k: the ordinal number of each blade, assigning 0 to the reference blade.

[0008] Fig. 11 shows the locating angle θ_k which indicates the location of the k-th blade.

[0009] When the blades 1 of the cross flow fan impeller pass near a stabilizer 10, noise is caused because of pressure fluctuation generated by the blades 1. The higher the distortion coefficient δ becomes, the more the noise "NZ" is reduced because correlation of the noise "NZ" among the blades 1 becomes less. On the other hand, rotational noise of the impeller generated by itself (this rotational noise is called the noise "N", hereinafter) becomes high especially in a low frequency band.

SUMMARY OF THE INVENTION

[0010] An object of the present invention is to provide an improved cross flow fan impeller, whereby the noise "NZ" can be reduced and the noise "N" in the low frequency band (lower than 600 Hz) can be also reduced.

[0011] According to the present invention, a cross flow fan impeller includes a plurality of division plates being perpendicular to a rotational axis of the impeller and a plurality of blades provided between each pair of the plurality of division plates. In the cross flow fan impeller of the invention, the blades are provided at intervals varied cyclically and each location of the blades is determined based on the following equation:

$$\theta_k = \theta_k 0 + \alpha \cdot d\theta \cdot \mathrm{Sin}(\beta \cdot d\theta \cdot k)$$

where,

θ_k: the locating angle of the k-th blade
$\theta_k 0$: the locating angle of the k-th blade if the blades were provided at equal intervals
α: a locating angle displacement coefficient
$d\theta$: the angle between each pair of adjacent blades if the blades were provided at equal intervals
β: a cyclic coefficient
k: the ordinal number of each blade, assigning 0 to the reference blade.

Brief Explanation of the Drawings

[0012] A more complete appreciation of the present invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a sectional diagram of a cross flow fan impeller according to a first embodiment of the invention;
Fig. 2 is a sectional diagram of an air conditioner including the cross flow fan impeller of the first embodiment;
Fig. 3 is a sign curve representing the variation of the location of the blades of the cross flow fan impeller of the first embodiment;
Fig. 4 shows a result of frequency analysis of noise generated in the cross flow fan impeller of the first embodiment;
Fig. 5 diagrammatically shows a skew angle of blades of a cross flow fan impeller of a fifth embodiment;
Fig. 6 shows a result of frequency analysis of a rotational noise generated in the cross flow fan impeller of the fifth embodiment;
Fig. 7 shows a sectional diagram of an internal unit of air conditioner according to the prior art;
Fig. 8 shows a cross flow fan impeller according to the prior art;
Fig. 9 shows a result of frequency analysis of rotational noise generated in a prior art cross flow fan impeller, where the blades are provided periodically;
Fig. 10 shows a result of frequency analysis of a rotational noise generated in another prior art cross flow fan impeller, where the blades are provided aperiodically;
Fig. 11 is a diagram which shows the locating angle θ_k which indicates the location of the k-th blade in a cross flow fan impeller according to the prior art; and
Fig. 12 is a diagram which explains the locating angle θ_k of the k-th blade in a cross flow fan impeller according to the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Embodiment 1.

[0013] Fig. 1 shows a first embodiment of a cross flow fan impeller 4 according to the present invention. Referring to Fig. 1, a plurality of blades 1 (including a reference blade 2) and a plurality of division plates 3 are provided in the impeller 4 of the first embodiment. Each of the blades 1 is located with a locating angle θ_k away from the reference blade 2 based on the following equation.

$$\theta_k = \theta_k 0 + \alpha \cdot d\theta \cdot \mathrm{Sin}(\beta \cdot d\theta \cdot k) \qquad (2)$$

where,

θ_k: the locating angle of the k-th blade
θ_k0: the locating angle of the k-th blade if the blades were provided at equal intervals
α: a locating angle displacement coefficient
$d\theta$: the angle between each pair of adjacent blades if the blades were provided at equal intervals
β: a cyclic coefficient
k: the ordinal number of each blade, assigning 0 to the reference blade.

[0014] In the cross flow fan impeller 4 of this embodiment, the total number of blades = 35, the locating angle displacement coefficient $\alpha = 0.2$, the cyclic coefficient $\beta = 2$, and the angle between each pair of blades if the blades were provided at equal intervals $d\theta = 2\pi/35$. In this case, $\theta_k0 = 2\pi \times k/35$. The blades 1 are respectively located in positions obtained by the above equation (2).

[0015] Fig. 12 explains the above equation (2). Based on the equation (2), for example, when k = 2, a location angle θ_2 is obtained as follows:

$$\theta_2 = \theta_2 0 + \alpha \cdot d\theta \cdot \mathrm{Sin}(\beta \cdot d\theta \cdot 2)$$

$$= 2\pi \times 2/35 + 0.2 \cdot 2\pi/35 \cdot \mathrm{Sin}\,\{2 \cdot (2\pi/35) \cdot 2\} \quad (3)$$

[0016] As shown in Fig. 12, the second element of the above equation (3), $\alpha \cdot d\theta \cdot \mathrm{Sin}(\beta \cdot d\theta \cdot k)$ shows displacement from θ_k0, that is, the locating angle in the case of providing blades at equal intervals. The maximum value of $\mathrm{Sin}(\beta \cdot d\theta \cdot k)$ is ±1 and the maximum value of the displacement is thus $\pm\alpha \cdot d\theta$. If $\alpha = 1.0$, some of the blades touches the next blade. If $\alpha = 0$, all the blades are located at the same intervals.

[0017] Fig. 2 shows an air conditioner including the cross flow fan impeller 4 of Embodiment 1 of the present invention. Referring to Fig. 2, a casing 6, an outlet 7, a plurality of inlet ports 8, a heat exchanger 9, and a stabilizer 10 are provided in an internal unit 5 of the air conditioner. Fig. 3 is a sine curve showing the variation location of the blades 1 according to Embodiment 1 of the invention, the points A through D corresponding to the 0° , 90° , 180° , and 270° positions, as indicated in Fig. 1.

[0018] In the cross flow fan impeller, the location of the blades 1 is varied cyclically. The noise "NZ" is modulated as shown in Fig. 4. A peak level of the noise "NZ" is dispersed and the noise level is thus decreased. On the other hand, the noise level of the noise "N" generated by the impeller itself is decreased because there is still correlation among the blades.

Embodiment 2.

[0019] As a second embodiment of the present invention, a modification of the cross flow fan impeller of the first embodiment is provided, where β, the cyclic coefficient, is a natural number greater than 2. The noise "NZ" is further modulated and it is effective to locate the plurality of blades cyclically.

Embodiment 3.

[0020] As a third embodiment of the present invention, a modification of the cross flow fan impeller of the first embodiment is provided, where β, the cyclic coefficient, is a natural even number greater than 2. The impeller is thus well-balanced mechanically.

Embodiment 4.

[0021] As a fourth embodiment of the present invention, a modification of the cross flow fan impeller of the first embodiment is provided, where α, the locating angle displacement coefficient, is a rational number and $0<\alpha<1$. Accordingly, the interval between each pair of adjacent blades does not become the same and none of the blades touches the next blade.

Embodiment 5.

[0022] According to a fifth embodiment of the invention, each location of the plurality of blades is determined by the equation (2) as in Embodiment 1, and the locating angle θ_k further includes a skew angle θ' as shown in Fig. 5. It is well-known that providing each blade with the skew angle θ' reduces the noise "NZ". To the configuration of Embodiment 1, the above feature is added, that is, each blade is provided with the skew angle θ'. The noise "NZ" is reduced further more than the cross flow fan impeller only including the feature of Embodiment 1.

Embodiment 6.

[0023] According to a sixth embodiment of the invention, the cyclic coefficient β is a natural number greater than 2 in the cross flow fan impeller of Embodiment 5. As a result, the noise "NZ" is further modulated and it is effective to locate the plurality of blades cyclically.

Embodiment 7.

[0024] According to a seventh embodiment of the invention, the cyclic coefficient β is a natural even number greater than 2 in the cross flow fan impeller of Embodiment 5. The impeller is thus well-balanced mechanically.

Embodiment 8.

[0025] According to an eighth embodiment of the invention, the locating angle displacement coefficient α is a rational number and $0<\alpha<1$ in the cross flow fan impeller of Embodiment 5. Accordingly, the interval between each pair of adjacent blades does not become the same and none of the plurality of blades touches the next blade.

[0026] Having thus described several particular embodiments of the present invention, various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the scope of the present invention. Accordingly, the foregoing description is by way of example only, and is not intended to be limiting. The present invention is limited only as defined in the following claims and the equivalents thereto.

Claims

1. A cross flow fan impeller (4), comprising:

   a plurality of division plates (3) perpendicular to a rotational axis of the impeller; and
   a plurality of blades (1) provided between each pair of division plates;

   wherein the blades are respectively located at intervals varied cyclically;
   characterised in that
   the blades are located in accordance with the following equation:

$$\theta_k = \theta_k 0 + \alpha \cdot d\theta \cdot \mathrm{Sin}(\beta \cdot d\theta \cdot k)$$

   where,

   θ_k: the locating angle of the k-th blade
   $\theta_k 0$: the locating angle of the k-th blade if the blades were provided at equal intervals
   α: a locating angle displacement coefficient
   $d\theta$: the angle between each pair of adjacent blades if the blades were provided at equal intervals
   β: a cyclic coefficient
   k: the ordinal number of each blade, assigning 0 to a reference blade (2).

2. The cross flow fan impeller of claim 1, wherein β is a natural number greater than 2.

3. The cross flow fan impeller of claim 1, wherein β is a natural even number greater than 2.

4. The cross flow fan impeller of claim 1, wherein α is a rational number and $0<\alpha<1$.

5. The cross flow fan impeller of claim 1, wherein the blades have a skew angle.

6. The cross flow fan impeller of claim 5, wherein β is a natural number greater than 2.

7. The cross flow fan impeller of claim 5, wherein β is a natural even number greater than 2.

8. The cross flow fan impeller of claim 5, wherein α is a rational number and $0<\alpha<1$.

Patentansprüche

1. Flügelrad (4) für Querstromlüfter, welches folgendes aufweist:

   - eine Vielzahl von Teilungsplatten (3), die senkrecht zu einer Drehachse des Flügelrads stehen, und
   - eine Vielzahl von Flügeln (1), die zwischen jedem Paar Teilungsplatten angeordnet sind,

   bei welchem die Flügel jeweils in zyklisch veränderten Abständen angeordnet sind,
   dadurch gekennzeichnet, dass die Flügel gemäß der folgenden Gleichung angeordnet sind:

   $$\Theta_k = \Theta_k 0 + \alpha \cdot d\Theta \cdot \sin(\beta \cdot d\Theta \cdot k)$$

   wobei:

   Θ_k: der Befestigungswinkel des k-ten Flügels ist,
   $\Theta_k 0$: der Befestigungswinkel des k-ten Flügels ist, falls die Schaufeln in gleichen Abständen angeordnet sind,
   α: ein Koeffizient für die Verlagerung des Befestigungswinkels ist,
   $d\Theta$: der Winkel zwischen jedem Paar benachbarter Flügel ist, falls die Flügel in gleichen Abständen angeordnet sind
   β: ein zyklischer Koeffizient ist,
   k: die Ordnungsnummer jedes Flügels ist, wobei 0 einem Bezugsflügel (2) zugeordnet wird.

2. Flügelrad für Querstromlüfter nach Anspruch 1, bei welchem β eine natürliche Zahl größer als 2 ist.

3. Flügelrad für Querstromlüfter nach Anspruch 1, bei welchem β eine natürliche gerade Zahl größer als 2 ist.

4. Flügelrad für Querstromlüfter nach Anspruch 1, bei welchem α eine rationale Zahl ist und die Beziehung $0 < \alpha 1$ gilt.

5. Flügelrad für Querstromlüfter nach Anspruch 1, bei welchem die Flügel einen schiefen Winkel aufweisen.

6. Flügelrad für Querstromlüfter nach Anspruch 5, bei welchem β eine natürliche Zahl größer als 2 ist

7. Flügelrad für Querstromlüfter nach Anspruch 5, bei welchem β eine natürliche gerade Zahl größer als 2 ist.

8. Flügelrad für Querstromlüfter nach Anspruch 5, bei welchem α eine rationale Zahl ist und die Beziehung $0 < \alpha 1$ gilt.

Revendications

1. Roue (4) pour une soufflante à courant transversal, comprenant:

   plusieurs plaques de division (3) perpendiculaires à un axe de rotation de la roue; et
   plusieurs aubes (1) prévues entre chaque paire de plaques de division;

   où les aubes sont situées respectivement à des intervalles qui varient d'une manière cyclique;
   caractérisée en ce que
   les aubes sont localisées en accord avec l'équation suivante:

   $$\theta_k = \theta_k O + \alpha \,.\, d\theta.\mathrm{Sin}(\beta.d\theta.k)$$

   où,

θ_k: l'angle de localisation de la $k^{ième}$ aube
θ_kO: l'angle de localisation de la $k^{ième}$ aube si les aubes étaient prévues à des intervalles égaux
α: un coefficient de déplacement de l'angle de localisation
$d\theta$: l'angle entre chaque paire d'aubes adjacentes si les aubes étaient réalisées à des intervalles égaux
β: un coefficient cyclique
k: le nombre ordinal de chaque aube, attribuant 0 à une aube de référence (2).

2. Roue pour une soufflante à courant transversal selon la revendication 1, où β est un entier naturel plus grand que 2.

3. Roue pour une soufflante à courant transversal selon la revendication 1, où β est un entier naturel pair plus grand que 2.

4. Roue pour une soufflante à courant transversal selon la revendication 1, où α est un nombre rationnel et $0<\alpha<1$.

5. Roue pour une soufflante à courant transversal selon la revendication 1, où les aubes présentent un angle d'inclinaison.

6. Roue pour une soufflante à courant transversal selon la revendication 5, où β est un entier naturel plus grand que 2.

7. Roue pour une soufflante à courant transversal selon la revendication 5, où β est un entier naturel pair plus grand que 2.

8. Roue pour une soufflante à courant transversal selon la revendication 5, où α est un nombre rationnel et $0<\alpha<1$.

Fig.1

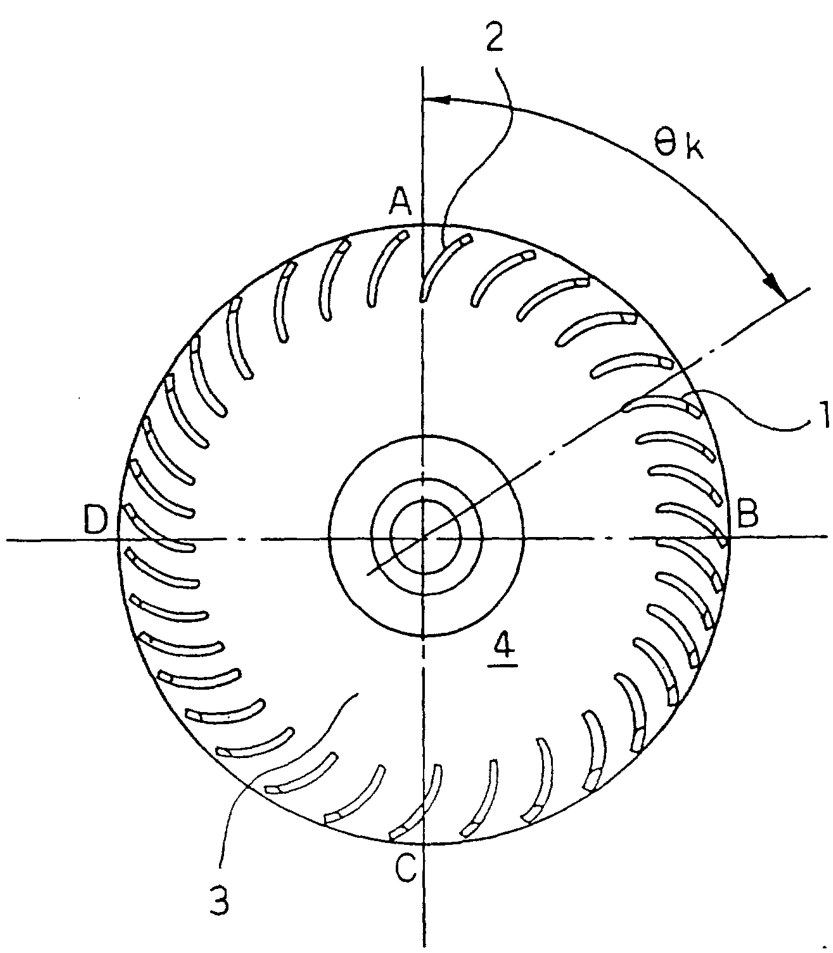

Fig.2

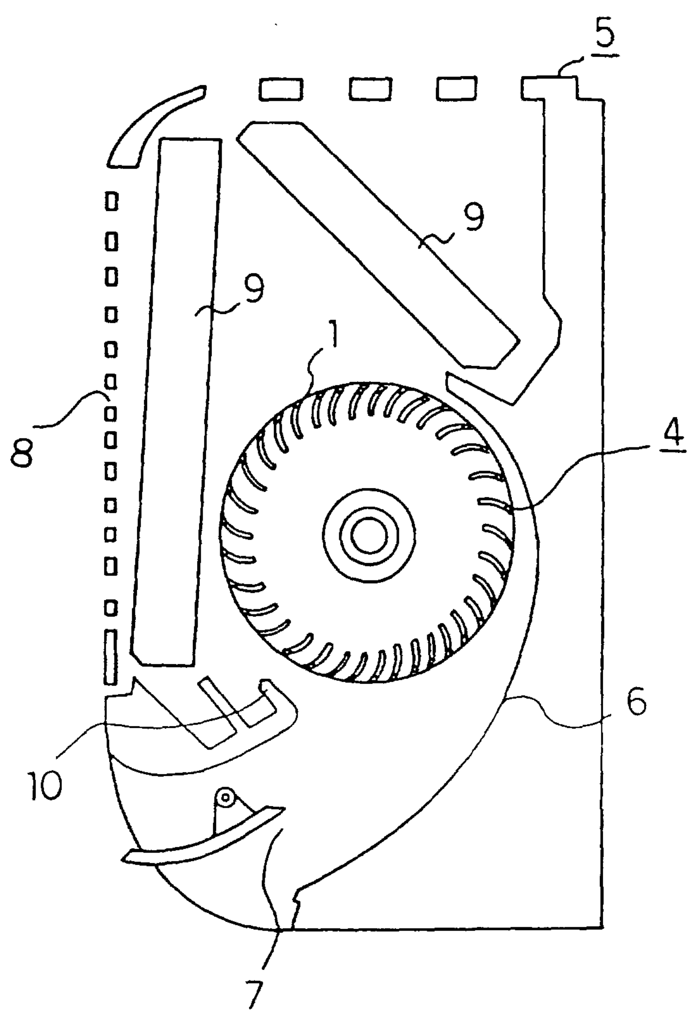

Fig.3

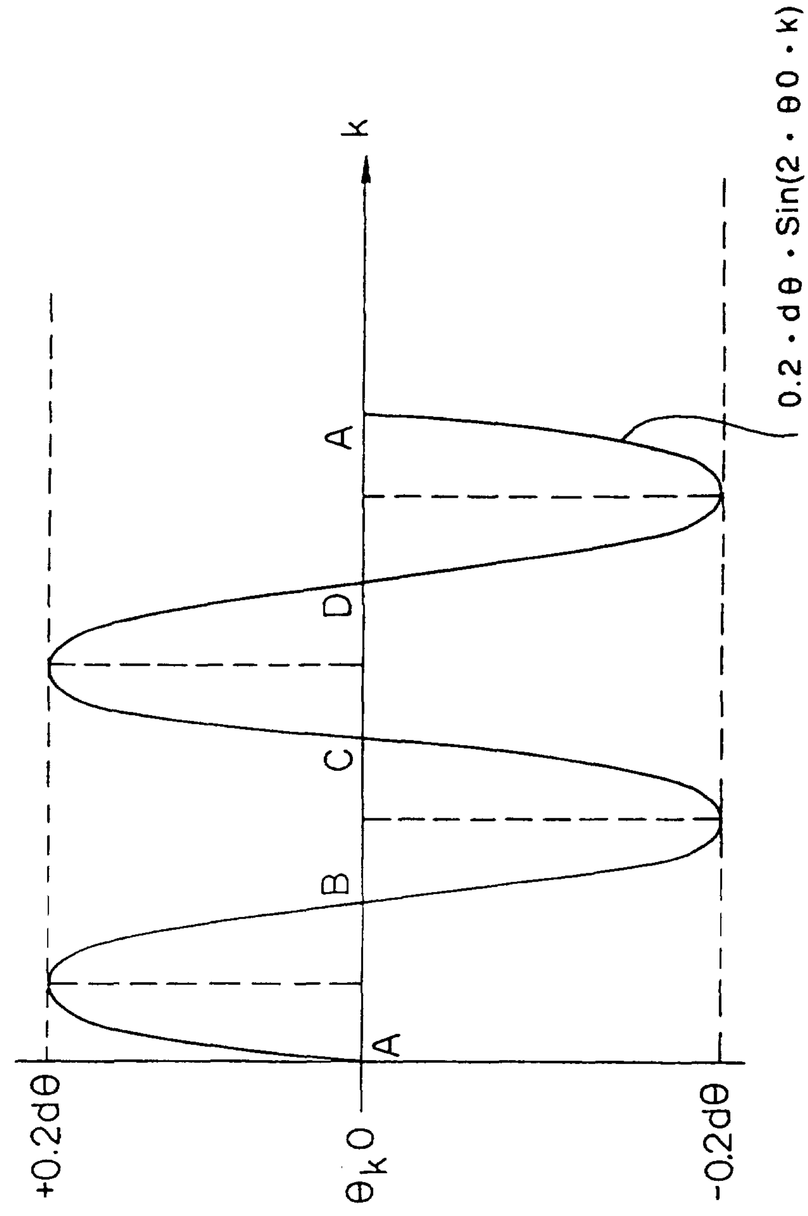

Fig.4

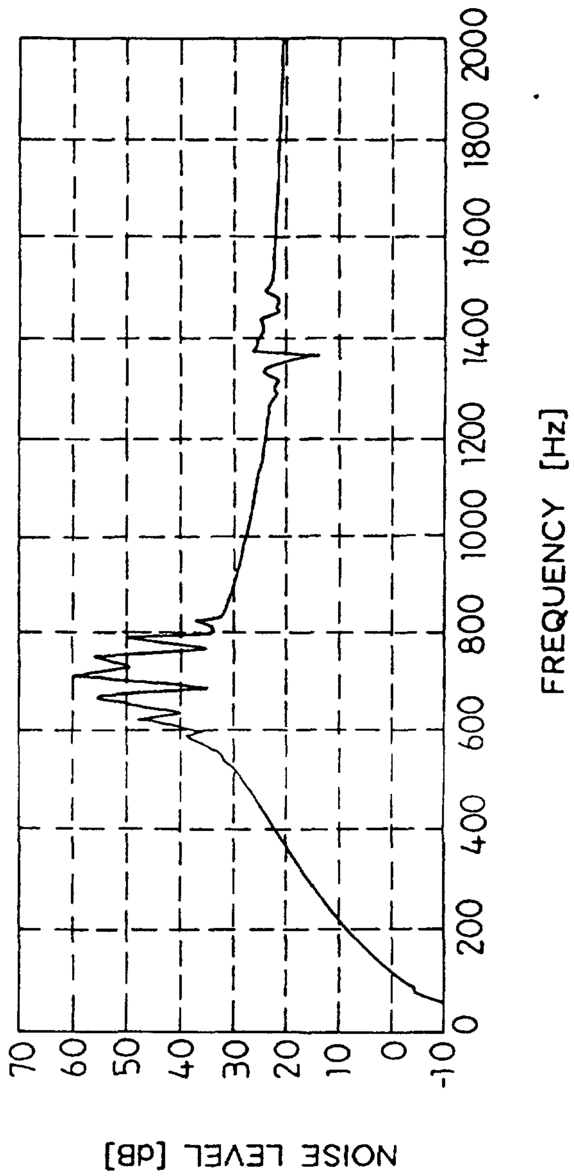
NOISE LEVEL [dB]
70
60
50
40
30
20
10
0
-10
0
200
400
600
800
1000
1200
1400
1600
1800
2000
FREQUENCY [Hz]

Fig.5

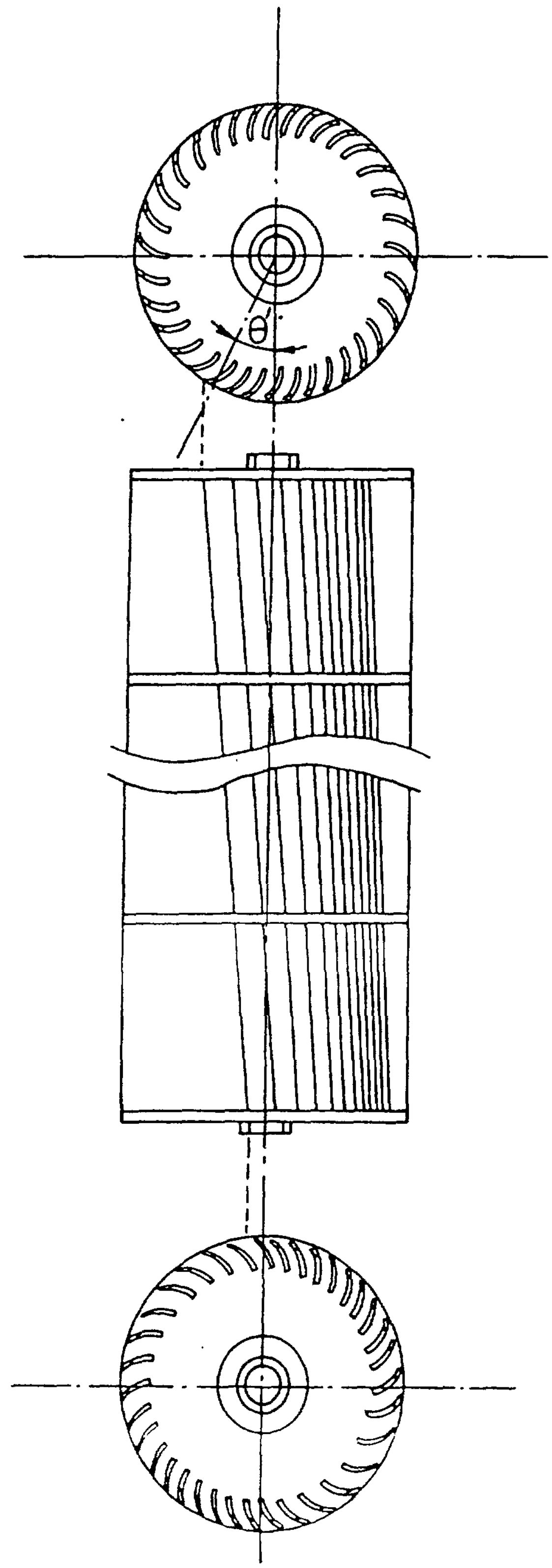

Fig.6

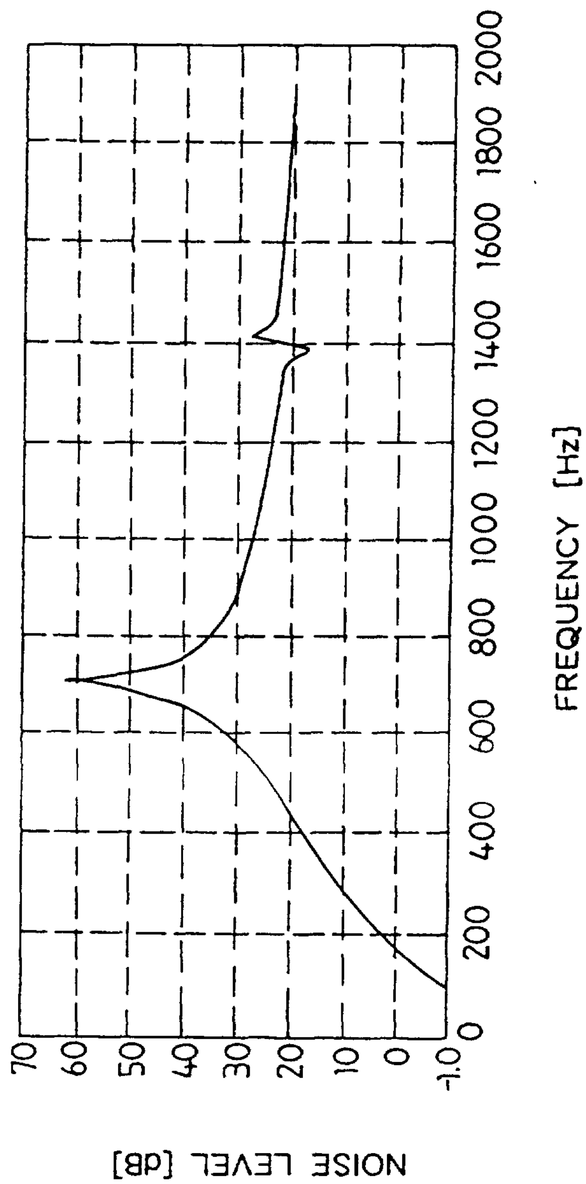
NOISE LEVEL [dB]
70
60
50
40
30
20
10
0
FREQUENCY [Hz]
0
200
400
600
800
1000
1200
1400
1600
1800
2000

Fig.7 PRIOR ART

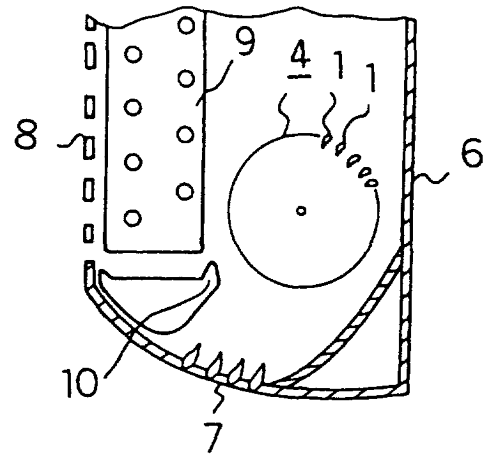

Fig.8 PRIOR ART

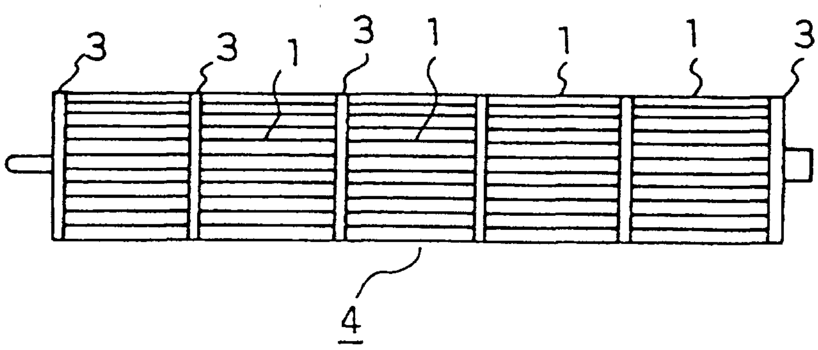

Fig.9 PRIOR ART

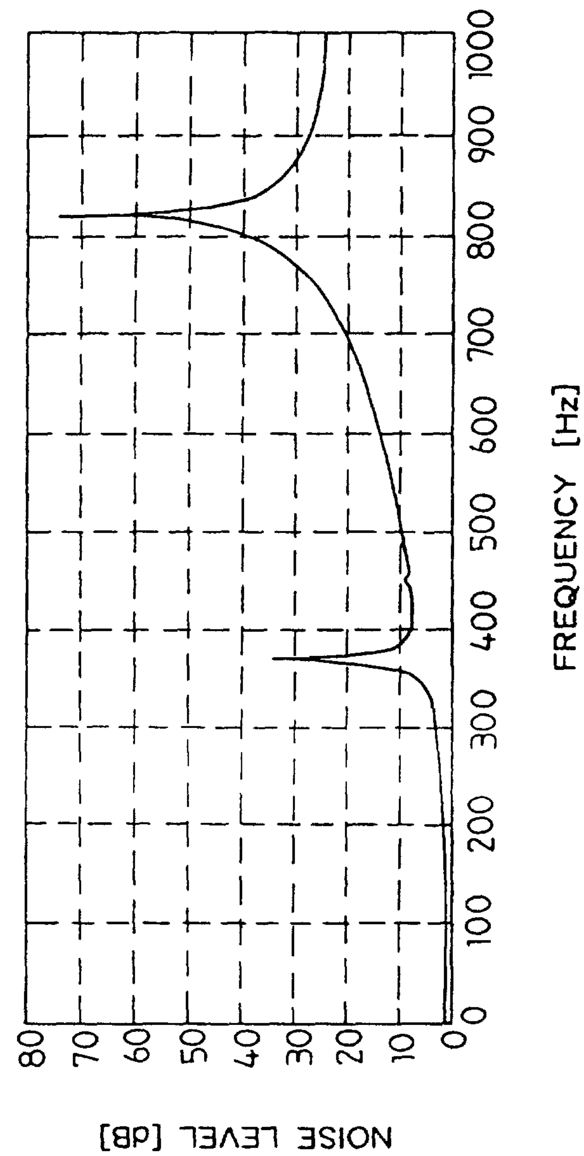

Fig.10 PRIOR ART

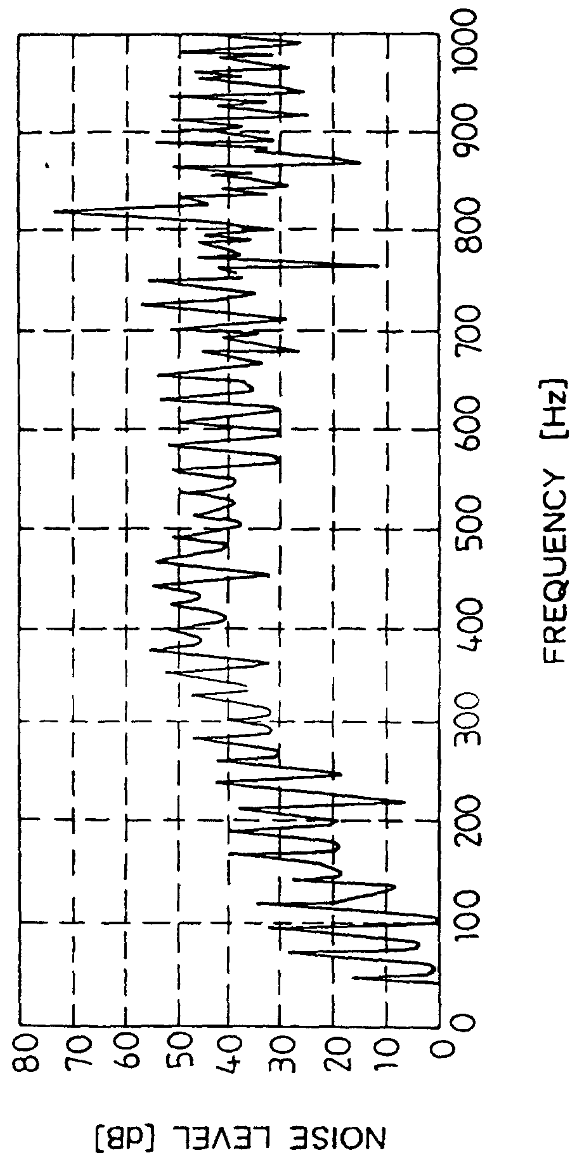

Fig.11 PRIOR ART

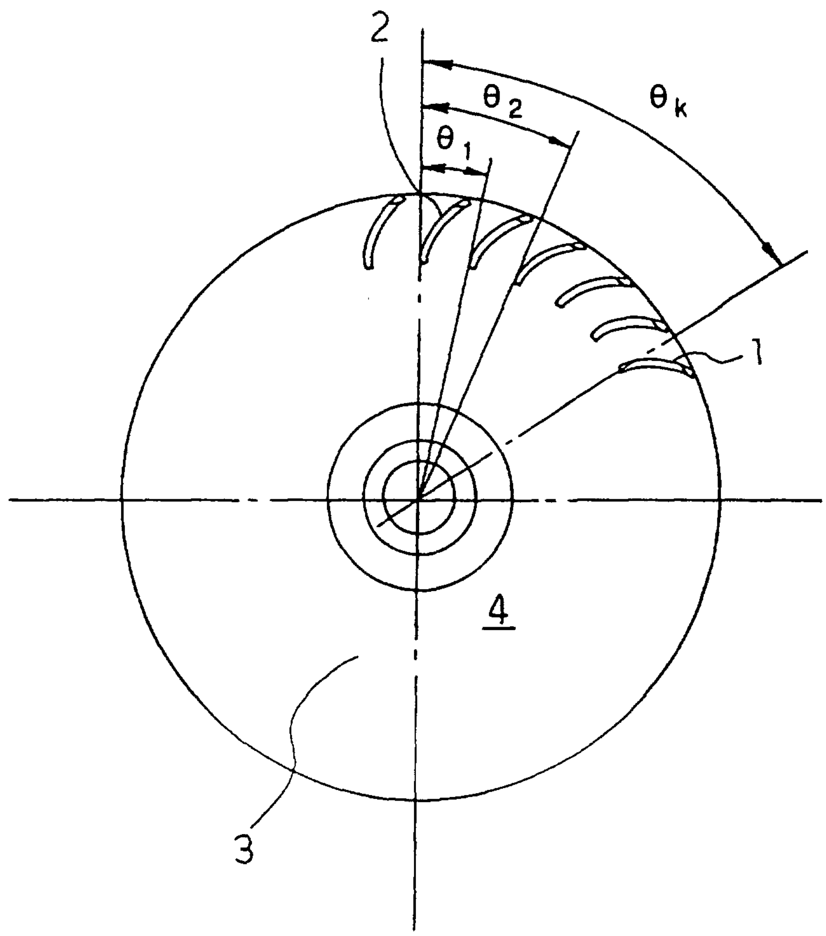

Fig.12