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(54) **AXIAL FAN WITH SERRATED BLADE LEADING EDGES**

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Description

[0001] The subject-matter of the invention is a low-speed axial fan suitable for mounting in a horizontal or vertical position, in particular in computer enclosures, CPU air coolers, CPU liquid coolers and other computer components, like computer PSUs.

[0002] Many modifications of fan blades are known in the state of the art. For example, a blower fan is known from the European application description EP3343045 A1, in which a part of the ridge of each blade is equipped with symmetrical serrations.

[0003] European Application Description EP3591238 A1 relates to an engine cooling system comprising an axial fan including a hub having an axis of rotation; a plurality of blades extending radially from the hub; and a fan cowl. Wherein each blade has a front edge and a rear edge, and wherein each blade has at least one flow element to reduce the airflow turbulence, selected from the group consisting of: a plurality of ridges positioned at the front edge, a plurality of serts positioned at the rear edge, and ribs extending transversely across each blade. The fan cowl, on the other hand, includes a guard with a wire extending between the first and second opening. Whereby the guard has a tapering section configured to restrict the flow of air moving from the first opening to the second opening.

[0004] In contrast, European Application Description EP3034886 A1 discloses a blade for a fan rotor having an end region facing the hub, a first blade side and a second blade side, wherein the blade has at least one rib in the end region facing the hub. The rib has an outer contour that simulates a flow profile and at least one rib having, at the rib start point, a rib base in the end region facing the hub and a rib base at the opposite rib end point, the rib base being positioned higher in the axial direction than the rib base at the rib end point; the rib has an end geometry in the area of the outer contour, the end geometry forms a sawtooth profile, the end geometry of the rib forms an alpha angle between -45° and $+45^\circ$ to the tangent to the contour of the surface of the other side of the blade, characterized in that: on the approach to the hub, the rib has a beta angle to the radial direction, with the beta angle ranging between -80° and $+80^\circ$.

[0005] Furthermore, the document CN 207 920 966 U discloses a fan according to the preamble of claim 1.

[0006] The purpose of the invention was to provide a new structure of a low-speed axial fan with improved acoustic properties.

[0007] The invention is a fan according to claim 1.

[0008] Preferably, the spacing between the serts is 1/7 of the length of the serrated leading edge of the blade.

[0009] The invention in question provides the following advantages:

- Improved psychoacoustic properties, i.e. reduction of the perceived noise;
- Thanks to the serrated leading edge of the fan blades

according to the invention, the solution ensures the elimination of prominent tonal sounds in the bands of about 315 Hz and about 3150 Hz;

- Elimination of tonal sounds of about 4350 Hz of prominent intensity;
- Relatively low production cost;
- The serrated shaping of the leading edge of the fan blades according to the invention can be produced by means generally known in the state of the art without increasing the cost of production.

[0010] The subject-matter of the invention is depicted in the embodiments shown in the drawing, wherein: fig. 1 shows a fan according to the invention in front view; fig. 2 shows the fan according to the invention in a frameless view; fig. 3 shows the tonal noise intensity of known low-speed axial fans; fig. 4 shows a diagram of the fans compared in example 4, where A) shows the test fan and B) shows the control fan; fig. 5 shows a comparison of the sound intensity emitted by the fan according to the invention and the control fan in accordance with PN-EN 61260-1:2015-01; fig. 6 shows a comparison of the sound spectrum emitted by the fan according to the invention and by the control fan, obtained by the Fourier analysis of the signal recorded at the output of an amplifier with the Z frequency characteristics.

Embodiment 1.

[0011] The axial fan according to the invention is designed to be mounted in a horizontal or vertical position in various cooling systems, e.g. it can be mounted in a computer enclosure. Whereby, in the field of computer cooling, the fan according to the invention may be used, for example, in air cooling of the CPU, liquid cooling of the CPU and other computer components like computer PSUs.

[0012] In this non-limiting embodiment, the axial fan according to the invention is mounted horizontally in the computer enclosure and is used for liquid cooling of the computer processor (i.e. the CPU).

[0013] As shown in fig. 1 and fig. 2, an axial fan according to the invention comprises a frame **1**, a motor and a plurality of blades **2** extending from the rotor towards the frame **1**. Whereby, said frame **1** comprises a support part **1a** and slats **1b** connected to the support part **1a** and fixing the motor and a plurality of fan blades **2** mounted on the motor rotor equipped with a fluid dynamic bearing (FDB).

[0014] Each of the plurality of blades **2** has a uniformly terminated trailing edge **3** and a substantially serrated leading edge **4** (which is indicated by a dashed line in fig. 1) provided with serrations **5**, which provide the serrated leading edge **4** with a shape approximating a sine wave that is vanishing in a direction towards a tip of the blade.

[0015] Whereby, in this non-limiting embodiment, the spacing between the individual serrations **5** is 1/7 of the length of the leading edge **4** of the blade **2**.

Embodiment 2.

[0016] Fan as in embodiment 1, except that the spacing between the individual serrations 5 is 1/5 of the length of the leading edge 4 of the blade 2.

Embodiment 3.

[0017] Fan as in embodiment 1, except that the spacing between the individual serrations 5 is 1/10 of the length of the leading edge 4 of the blade 2.

Embodiment 4.

[0018] The sound generated by the low-speed axial fan according to embodiment 1 consists of tonal components and broadband noise with a continuous spectrum. The main source of the tonal components is the movement of the rotor. The fan generates tonal noise consisting of tones corresponding to the rotor blade passing frequency (BPF) and multiples of the BPF. Other sources of tonal noise are aerodynamic effects: stall cycling around the rotor and variations in rotor blade forces due to blade position relative to asymmetrical parts of the fan cowl.

[0019] The sources of broadband random frequency noise are mainly aerodynamic effects: turbulence due to geometric imperfections of the rotor, random fluctuations in pressure and velocity of the air stream entering the fan, and air vortices at the ends of the rotor blades and behind the trailing edge of the rotor blades (Neise, W. and Michel, U., AERODYNAMIC NOISE OF TURBOMACHINES, German Aerospace Center, Berlin 1994; Moreau, S. et al, Toward the prediction of low-speed fan noise, Center for Turbulence Research 2006).

[0020] The intensity of tonal noise is usually concentrated in the low frequency band, from 100 to 2000 Hz (fig. 3). The fan in question, with a speed of 1600 rpm and a rotor with 9 blades, generates tonal noise with component frequencies of 240 Hz and subsequent multiples of 240 Hz. In the 100-1000 Hz band, the tonal components have a much higher intensity than the broadband noise. In the band above 1000 Hz, the intensity of the sound is dominated by the broadband noise.

[0021] The sense of hearing reacts differently to pure tones than to broadband noise. First, pure tones are perceived to be louder and better heard than white noise of the same intensity (*The assessment of noise in audio-frequency circuits, BBC Research Department Report EL-17, British Broadcasting Corporation, Kingswood 1968*). Because of this observation, the isophones for the broadband noise are different from the isophones for the tonal sounds, and acoustics uses different frequency correction characteristics (e.g. ITU-R Recommendation 468) to study noise in an acoustic circuit.

[0022] Secondly, sources of tonal sound are easier to locate in space. The sense of hearing relies, among other things, on the phase difference between the sound reaching the right and the left ear. This difference is more

difficult to detect if the sound does not consist of a pure tone.

[0023] Thirdly, a tonal sound masks the audibility and recognition of other sounds of a frequency occupying the same critical band, i.e. of similar frequency.

[0024] Broadband noise is perceived as quieter, is more difficult to locate, is less likely to mask the audibility of other ambient sounds, and is more likely to itself be masked by ambient sounds. For these reasons, it is desirable to reduce the tonal noise produced by the fan, especially in octaves where the broadband noise is much less intense. Replacing tonal noise with broadband noise of the same acoustic power reduces the annoyance of the perceived sound. As high-frequency sounds are more strongly attenuated by air (Lamancusa, J. S., Noise control, Pennsylvania State University, State College 2009; https://www.mne.psu.edu/lamancusa/me438/10_osp.pdf), swapping noise for another noise with the same acoustic power but with a higher frequency band is also beneficial.

[0025] In order to demonstrate that the fan according to the invention is superior to the state of the art, the sound spectrum emitted by the fan according to the invention (test fan) was compared to that emitted by an identical fan with blades with curved leading edges without serrations (control fan) (fig. 4).

[0026] Measurement instruments used:

- Sonopan DSA-50 digital sound analyser with Sonopan PW21LG microphone preamplifier, Sonopan WK-21 measurement microphone and Sonopan PD5L6 microphone extension cable. A class 1 instrument meeting the requirements of the following standards: PN-EN 61672-1:2005/A1:2007, PN-EN 61672-2:2005, PN-EN 61260:2000/A1:2004, PN-ISO 7196:2002;
- Rigol DS1054Z digital oscilloscope connected to a PC.

[0027] The tested fans were mounted on a test stand consisting of:

- a heat sink designed to dissipate heat from the processor,
- a microphone,
- a linear guide allowing the fan to be positioned at the desired distance from the microphone.

[0028] The test rig was placed in an anechoic chamber with dimensions of 110×110×170 cm. The fans were placed at a distance of 30 cm from the microphone, in such a way that the fan axis and the microphone axis overlapped. The fans were operated at a speed of 1600 rpm ($\pm 1\%$) powered by 12.0 V DC and controlled by a 25 kHz PWM waveform with a maximum level of 4.4 V, as intended.

[0029] In the first part of the experiment, the sound of the running fan was analysed by a Sonopan DSA-50

digital sound analyser in the $\frac{1}{3}$ octave analyser mode using the Z-correction characteristic. Each measurement lasted 12 seconds.

[0030] In the first part of the experiment, the intensity of the sound emitted by both fans was compared with a bandwidth of $\frac{1}{3}$ of an octave, with the nominal frequencies in accordance with the recommendation of PN-EN 61260-1:2015-01 (*PN-EN 61260-1:2015-01 Electroacoustics - Bandpass filters with a width of an octave and part of an octave*). The results of the performed analysis are shown in fig. 5. Based on the results obtained, it was found that the fan according to the invention (i.e. the tested fan) emitted noise of a significantly lower intensity in bands centred around 250 Hz, 315 Hz, 4 kHz and 5 kHz, compared to the control fan.

[0031] In the second part of the experiment, the sound of the running fan was collected by a microphone and a Sonopan preamplifier set to the Z-correction characteristic. The course of the signal after it passed the preamplifier was recorded with an oscilloscope at a sampling frequency of 100 kHz for 12 seconds. The recorded signal was subjected to computer analysis with a view to detecting the tonal and stochastic components. An FFT time-frequency resolution of 1.2×10^6 samples, in the Hann time window, was performed. The acoustic power in the $\frac{1}{9}$ octave bands, proportional to the bands defined by the PN-EN 61260-1:2015-01 standard, was also calculated.

[0032] In the second part of the experiment, the spectrum of the sound emitted by both fans obtained by the Fourier's time-frequency duality analysis of the signal recorded at the output of an amplifier with the Z frequency characteristics was compared. The spectrum was additionally distorted in accordance with the ITU-R 468 recommendation to represent a similar perception of the noise level composed mainly of broadband noise. The results are shown in fig. 6.

[0033] The analysis has shown that the sinusoidal shaping of the leading edge of the rotor blades eliminates the tonal sound at a frequency of about 315 Hz, the intensity of which was higher than that of any other tonal component of the emitted sound. The said shaping also eliminates a tonal sound at around 4350 Hz with a distinctive intensity.

Claims

1. A low-speed axial fan for mounting in a horizontal or vertical position, in particular in computer enclosures, comprising a frame, a motor and a plurality of blades extending from the rotor towards the frame, the frame comprising a support part and slats connected to the support part and fixing the motor and the plurality of fan blades mounted on the motor rotor, wherein

each of the plurality of blades (2) has a uniformly

terminated trailing edge (3) and a substantially serrated leading edge (4) provided with serrations (5) such that the serrated leading edge has a shape approximating a sine wave, wherein the spacing between the individual serrations (5) is $\frac{1}{10}$ to $\frac{1}{5}$ of the length of the leading edge (4) of the blade (2);

characterised in that

the rotor is fitted with a fluid dynamic bearing (FDB) and in that the shape of the serrated leading edge approximates a sine wave that is vanishing in a direction towards the tip of the blade.

2. Fan according to claim 1, characterised in that the spacing between the individual serrations (5) is $\frac{1}{7}$ of the length of the leading edge (4) of the blade (2).

Patentansprüche

1. Axialventilator mit niedriger Drehzahl zur Montage in einer horizontalen oder vertikalen Position, insbesondere in Computergehäusen, umfassend einen Rahmen, einen Motor und eine Vielzahl von Flügeln, die sich vom Rotor zum Rahmen erstrecken, wobei der Rahmen ein Trägerteil und mit dem Trägerteil verbundene Schlitze umfasst, die den Motor und die Vielzahl der am Motorrotor montierten Ventilatorflügel fixieren, wobei jeder der Vielzahl von Flügeln (2) eine gleichmäßig abschließende Hinterkante (3) und eine im Wesentlichen gezahnte Vorderkante (4) aufweist, die mit Zahnungen (5) versehen ist, so dass die gezahnte Vorderkante eine Form aufweist, die einer Sinuswelle angenähert ist, wobei der Abstand zwischen den einzelnen Zahnungen (5) $\frac{1}{10}$ bis $\frac{1}{5}$ der Länge der Vorderkante (4) des Flügels (2) beträgt;

dadurch gekennzeichnet, dass der Rotor mit einem fluiddynamischen Lager (FDB) ausgestattet ist und dass die Form der gezahnten Vorderkante einer Sinuswelle angenähert ist, die in einer Richtung zur Blattspitze hin ausläuft.

2. Ventilator nach Anspruch 1, **dadurch gekennzeichnet, dass** der Abstand zwischen den einzelnen Zahnungen (5) $\frac{1}{7}$ der Länge der Vorderkante (4) des Flügels (2) beträgt.

Revendications

1. Ventilateur axial à basse vitesse pour montage en position horizontale ou verticale, en particulier dans des boîtiers d'ordinateur, comprenant un cadre, un moteur et une pluralité de pales s'étendant du rotor vers le cadre, le cadre comprenant une partie de support et des fentes reliées à la partie de support et

fixant le moteur et la pluralité de pales de ventilateur montées sur le rotor du moteur, dans lequel chacune de la pluralité de pales (2) présente un bord de fuite (3) se terminant de manière uniforme et un bord d'attaque (4) sensiblement dentelé pourvu de dentelures (5) de sorte que le bord d'attaque dentelé présente une forme approchant une onde sinusoïdale, dans lequel l'espacement entre les dentelures individuelles (5) est de $1/10$ à $1/5$ de la longueur du bord d'attaque (4) de la pale (2) ;

caractérisé en ce que le rotor est équipé d'un palier hydrodynamique (FDB) et **en ce que** la forme du bord d'attaque dentelé approche une onde sinusoïdale qui s'estompe en direction de l'extrémité de la pale.

2. Ventilateur selon la revendication 1, **caractérisé en ce que** l'espacement entre les dentelures individuelles (5) est de $1/7$ de la longueur du bord d'attaque (4) de la pale (2).

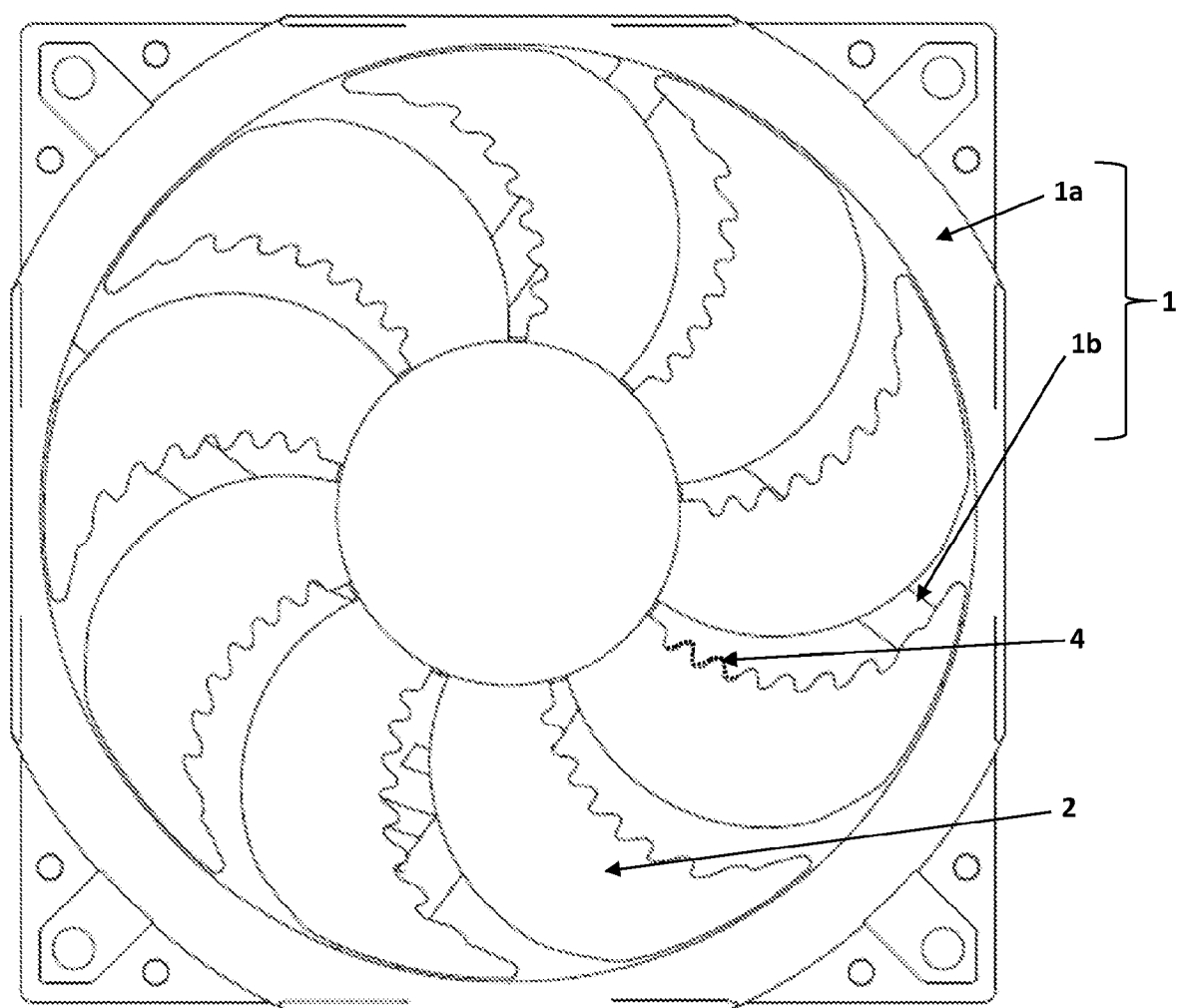


Fig. 1

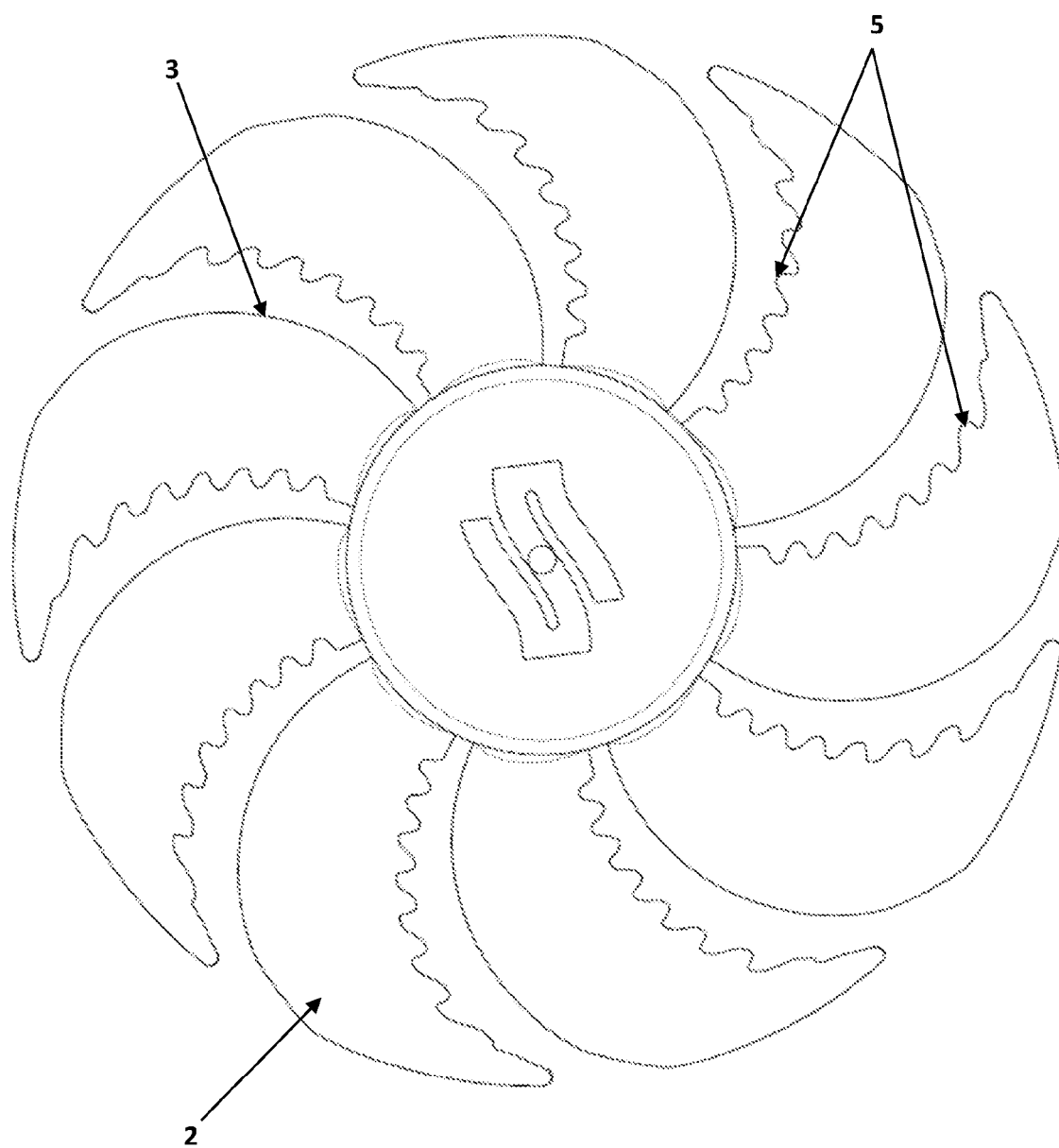


Fig. 2

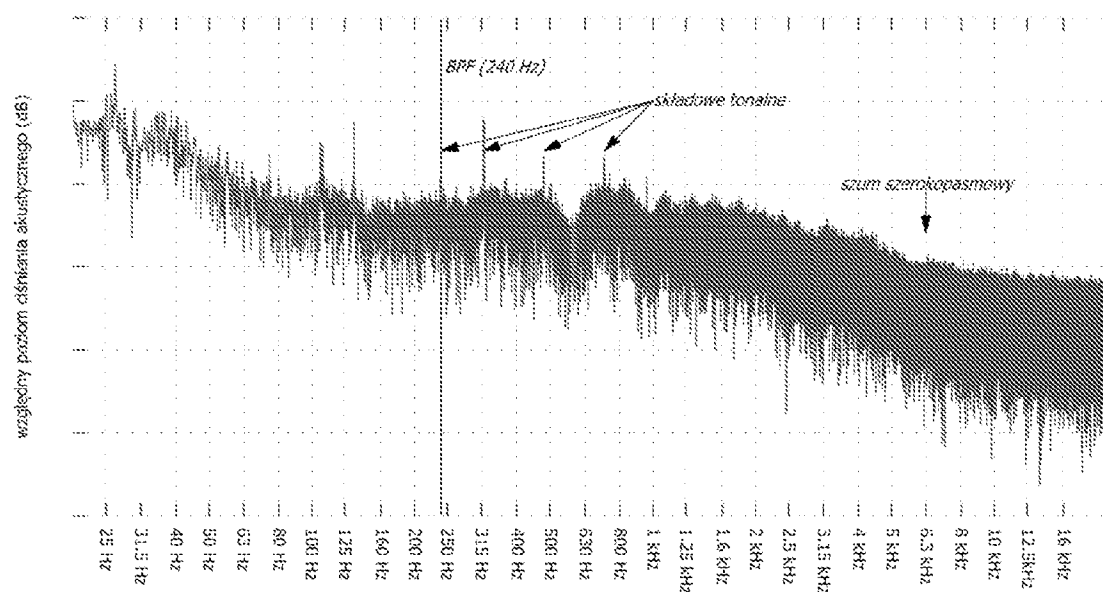


Fig. 3

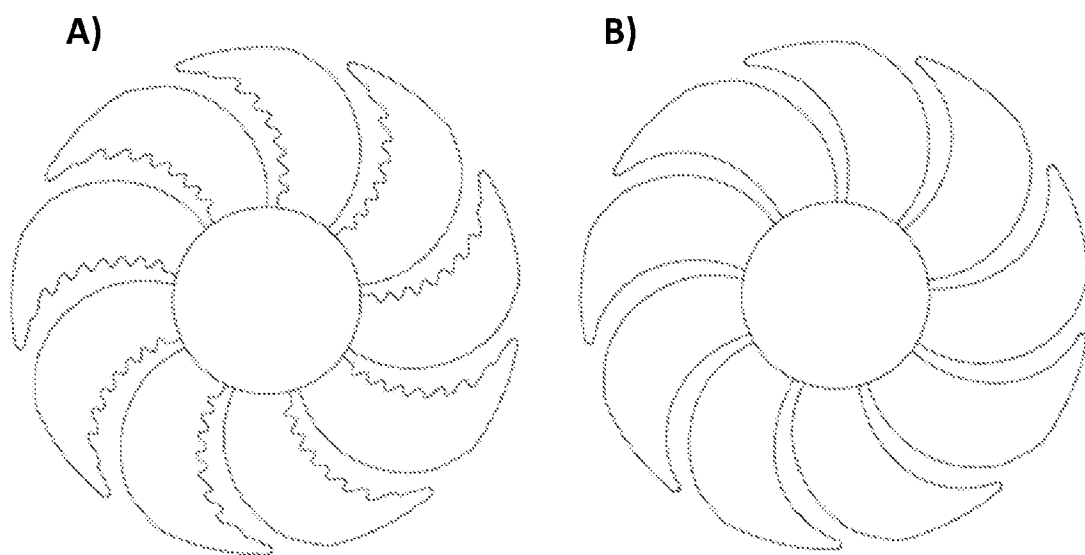


Fig. 4

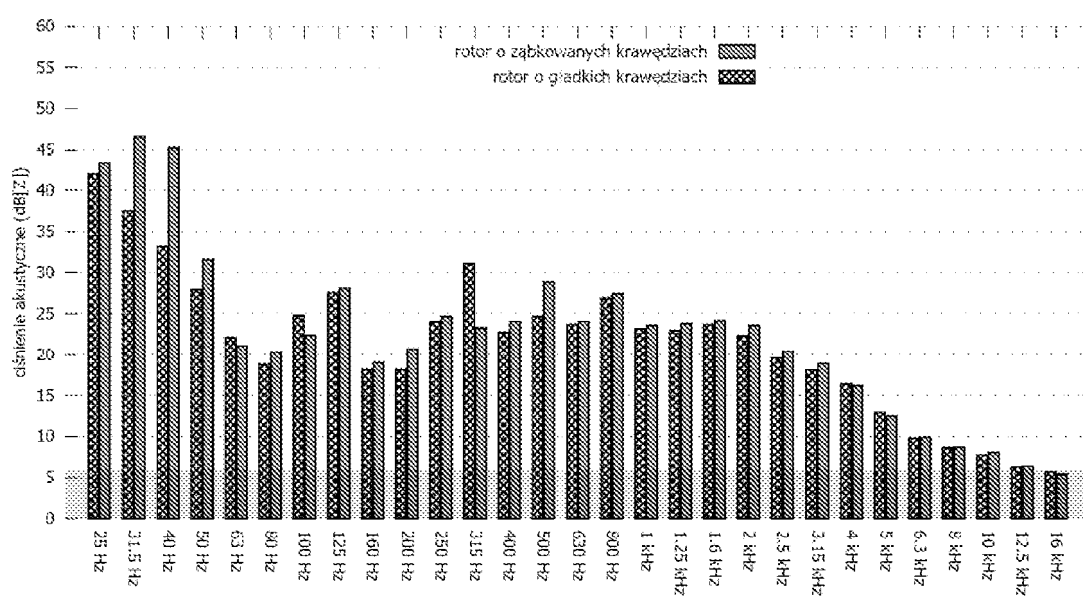


Fig. 5

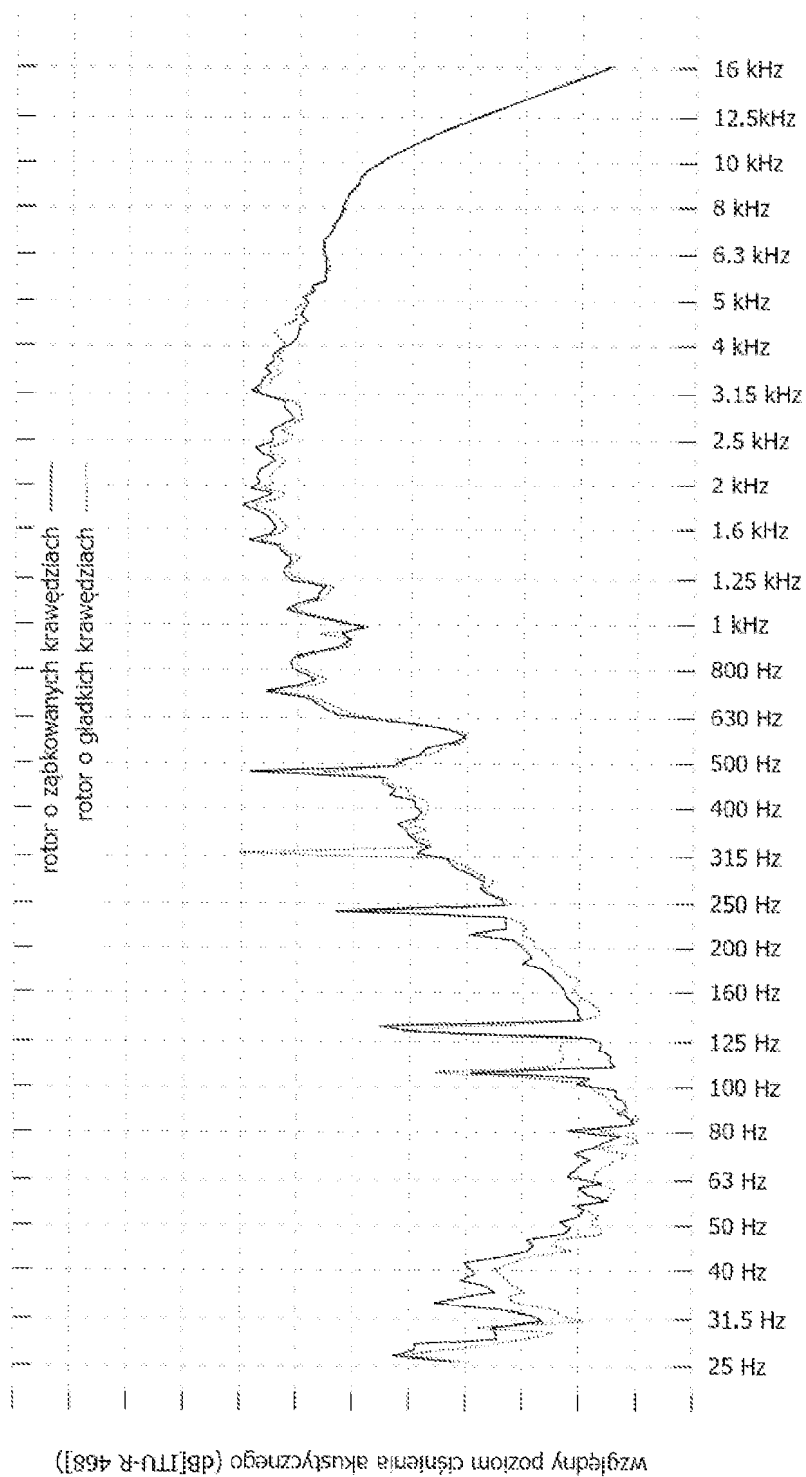


Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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