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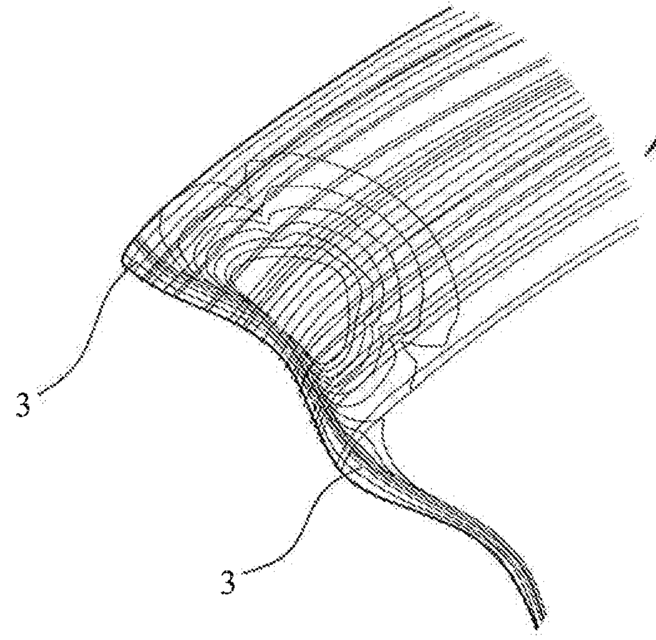


FIG. 1

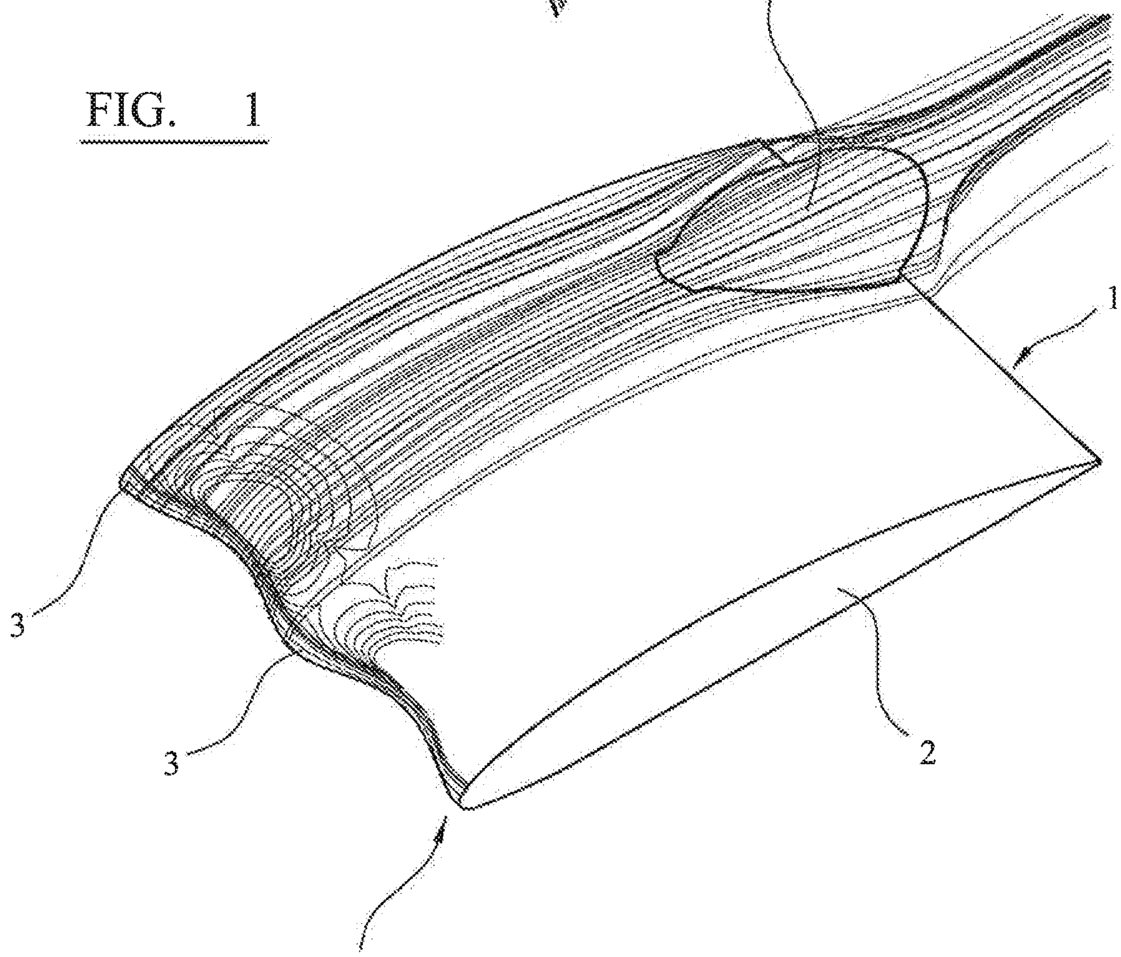


FIG. 2

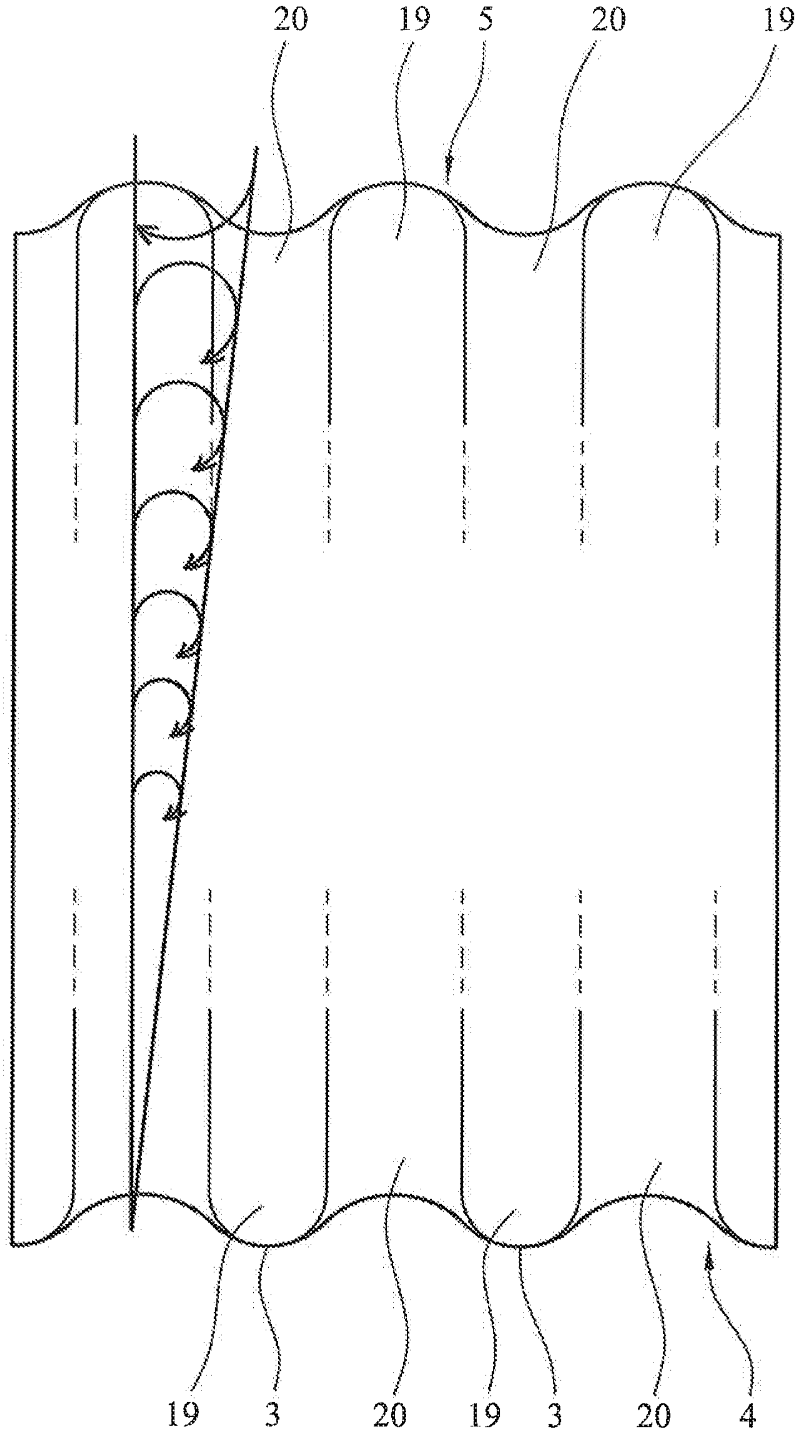


FIG. 3

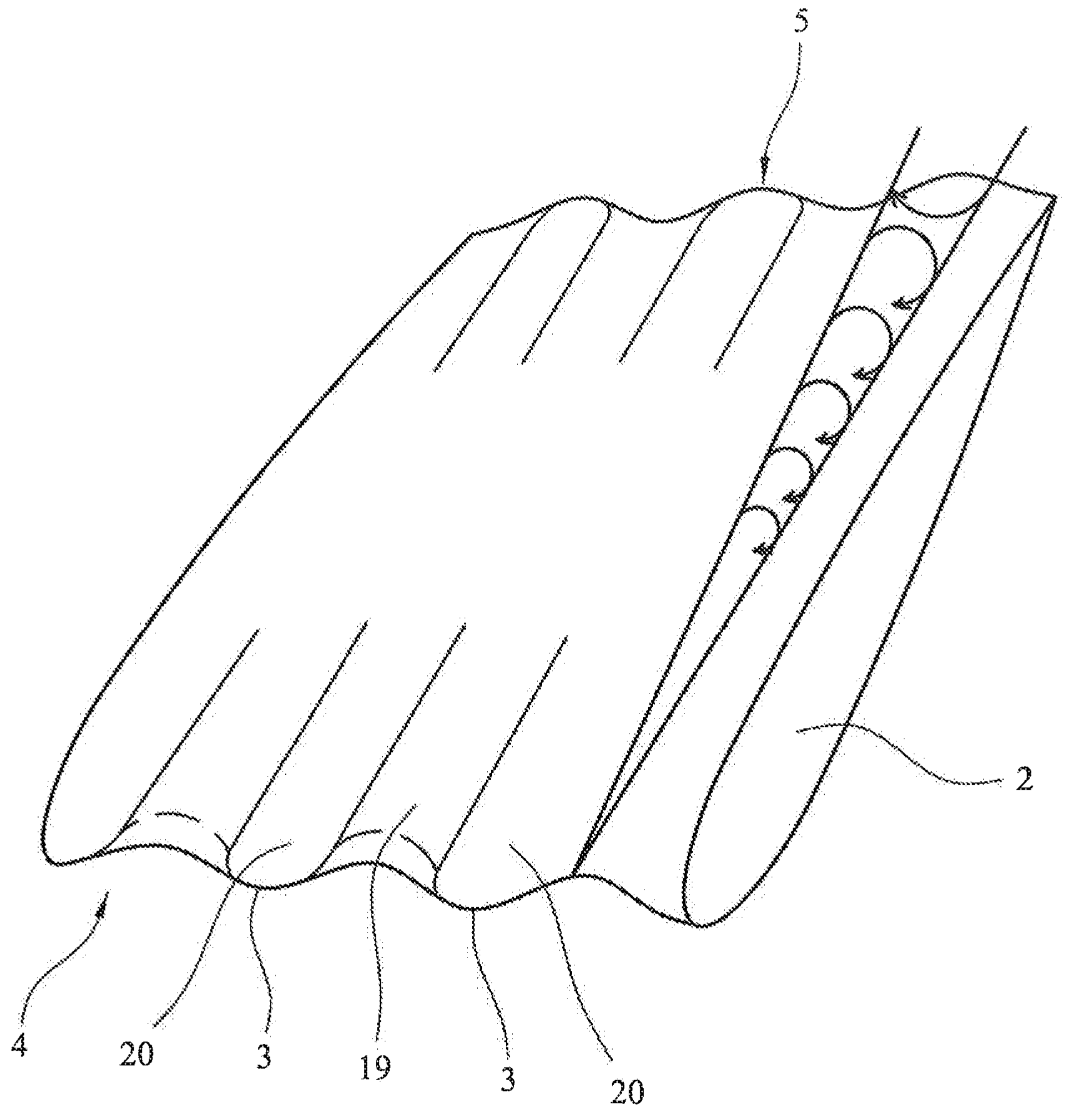


FIG. 4

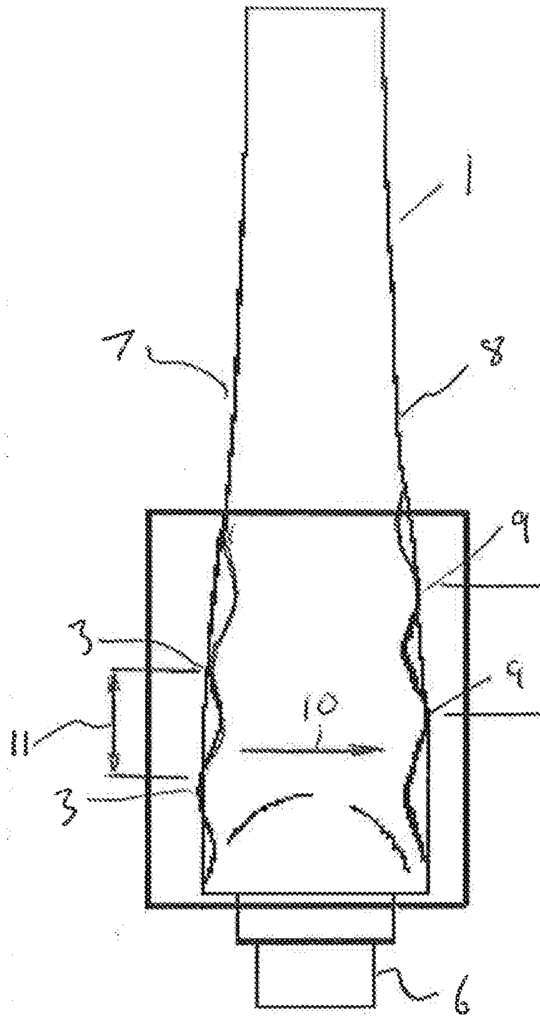


FIG 5

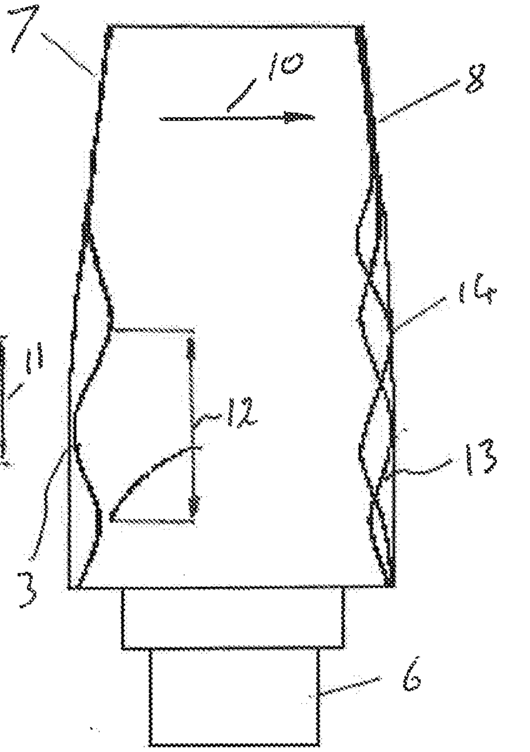


FIG 6

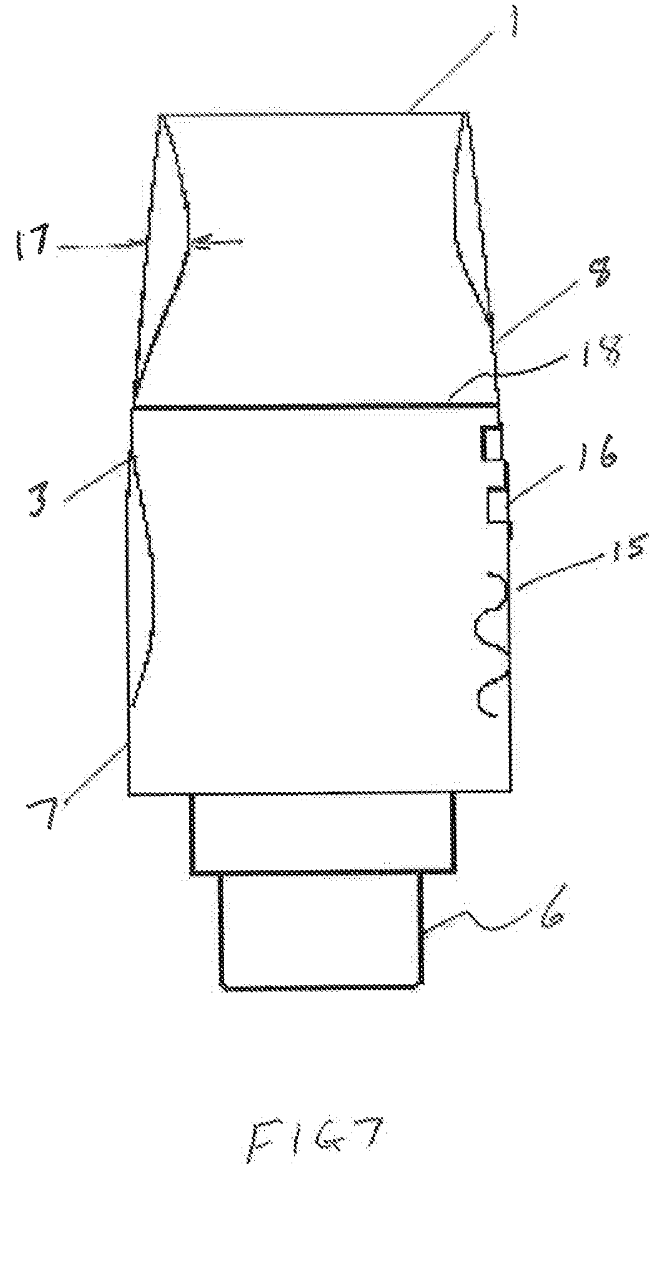


FIG7

# Air Movement Fans

The present invention relates to air movement fans particularly but not exclusively, axial fans having a plurality of elongate fan blades extending generally radially from a hub.

Such fan blades are of an aerofoil or generally planar transverse cross-section and are inclined at an angle of attack relative to the radial plane in which the fan rotates, the blade having a leading edge and a trailing edge. In order to improve the efficiency of such fans and to control the incidence of stall, it is known, from US Patent No.6431498 for example, to provide protrusions, also known as tubercles, extending from the leading edge. Such protrusions can improve the airflow and control the creation of vortices over the surface of the fan blade.



The present invention seeks to provide further improvements to fan blades to increase the efficiency and stall characteristics of the fan and also to reduce the generation of noise.

According to the present invention there is provided an air movement axial fan having a plurality of blades extending generally radially from a hub, each blade having a leading edge and a trailing edge, both the leading edge and the trailing edge having a plurality of protrusions spaced along their length, wherein, in plan view, in the transverse direction across the fan, the protrusions on the trailing edge are offset in the radial direction with respect to those on the leading edge, wherein the protrusions on the leading edge merge into elongate bumps projecting from a surface of the blade and extending towards the trailing edge and the protrusions on the trailing edge merge into bumps projecting from said surface of the blade and extending towards the leading edge.

In a preferred form, the bumps extending from the leading and trailing edges merge smoothly with said surface of the blade to form valleys between adjacent protrusions.

In a preferred embodiment, the protrusions on the leading edge and trailing edge describe, in plan view, a generally wavelike profile along the edge, the wavelike profile preferably being sinusoidal, arcuate, rectangular or hyperbolically tangent.

In a preferred embodiment, the offset is half the distance between adjacent protrusions.

In another embodiment, the wavelength and/or the wave amplitude of the protrusions is varied along the length of the fan blade. The wavelength and/or the wave amplitude at any particular point on the fan blade may be dependent on the chord of the fan blade.

In another preferred embodiment, the fan is a unidirectional axial fan having a plurality of blades extending generally radially from a hub. In a further development, the fan is a reversible bidirectional axial fan having a plurality of blades extending generally radially from a hub, in which case, the blades are symmetrical in transverse cross-section to provide identical performance in both directions of rotation.

The protrusions towards the outer tip of the blade and/or the hub are gradually smaller and may be omitted altogether.

Preferred embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:-
Figures 1 and 2 show schematically the flow of air over an aerofoil having protrusions on the leading edge,
Figures 3 and 4 show respectively plan and perspective schematic views of the profile of protrusions and bumps on a fan blade for the generation of vortices, and
Figure 5, 6 and 7 show schematically part of a fan blade with different types of protrusions.

Referring to Figures 1 and 2 there is shown part of a fan blade 1 of an axial fan for controlling air movement, the blade 1 having a generally aerofoil cross-section 2 with protrusions 3 extending from the leading edge 4 of the blade 1. Reference is also made to

Figures 3 and 4 which show the protrusions 3 merge into bumps 19 on the surface of the blade which merge smoothly into the surface of the blade. As a result, valleys 20 are formed between adjacent protrusions 3 and these valleys merge smoothly into the bumps 19 and into the main surface of the blade. As a result of the protrusions 3, the blade movement causes the build-up of pressure and the generation of vortices on either side of each protrusion which are contra rotating.. This generates an air stream in the form of a vortex which passes along the blade and which remains attached to the blade profile both in pre-and post-stall operations. This helps the vortex to stay attached to the blade 1 until separation occurs at the trailing edge 5 of the blade 1. The protrusions 3 at the leading edge thus induces the formation on either side of a protrusion of counter-rotating vortices.

Figure 5 shows a schematic view of a fan blade having a connector part 6 through which the blade is connected to a hub of an axial fan. The blade has a leading edge 7 having a plurality of protrusions 3, only two of which are shown, which extend along the length of the leading edge 7. The protrusions have a fixed wavelength, reference 11. The trailing edge 8 of the fan blade also has a plurality of protrusions 9 having the same wavelength 11 extending along the length of the blade 1. In this example the protrusions 9 on the trailing edge are offset in the transverse direction 10 of the blade, that is in the direction along which air passes the blade by half a wavelength.

Figure 6 shows a similar view of part of a fan blade 1 having on the leading edge 7 protrusions having a wavelength 12, and on the trailing edge 8 indications of two alternative waveform dispositions. A first alternative waveform 13 is aligned with the waveform of the protrusions 3 on the leading edge but a second possibility is shown, reference 14, in which the wavelength of the trailing edge of protrusions are offset slightly with respect to the protrusions 3 on the leading edge. It has been found that, in operation, when air passes across the fan as it rotates, there is a tendency as a result of centrifugal force for the air to move up towards the tip of the fan under the influence of centrifugal force. By offsetting the protrusions at the trailing edge the vortices follow the desired path to exit the trailing edge at the desired valley. In one form, it is possible for the protrusions and hence the valleys between them on the trailing edge at least to be inclined at a slight angle upwardly towards the tip at the trailing edge so that the protrusions and valleys are aligned with the natural flow path of the air caused by centrifugal force. This has the advantage that unwanted turbulence caused by the airflow hitting the side of a valley at a slight angle is reduced.

Figure 7 shows a further schematic view of part of a fan blade 1 with alternative constructions of protrusions. On the leading edge 7 there is shown one protrusion 3 having a relatively large wavelength whilst on the trailing edge there is shown alternative forms of protrusions. Whereas the protrusions shown in Figures 5 and 6 show essentially sinusoidal waveforms, Figure 7 shows a first example, reference 15, of protrusions having an arcuate profile. Reference 16 shows protrusions having a rectangular profile.

The wavelength 11 and wave amplitude 17 are determined by operating parameters of the fan, including the ratio of the protrusion amplitude and the chord length 18 of the blade, as shown in figure 7, to ensure that the dimension and nature of the vortices to be controlled are such as to control the flow separations at the trailing edge of the blade. The parameters of the protrusions may be made smaller towards the tip and the root of the blade and may even be omitted in the regions adjacent the tip and the root so that only the centre portion of the blade has protrusions.

When the blade is of a unidirectional axial fan, the profile and parameters of the protrusions on the leading edge and trailing edge may be different but when the blade is of a bidirectional axial fan, the blade is symmetrical in transverse cross-section to provide equal performance in both directions of rotation.

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CLAIMS

1. An air movement axial fan having a plurality of blades extending generally radially from a hub, each blade having a leading edge and a trailing edge, both the leading edge and the trailing edge having a plurality of protrusions spaced along their length, wherein, in plan view, in the transverse direction across the fan, the protrusions on the trailing edge are offset in the radial direction with respect to those on the leading edge, wherein the protrusions on the leading edge merge into elongate bumps projecting from a surface of the blade and extending towards the trailing edge and the protrusions on the trailing edge merge into bumps projecting from said surface of the blade and extending towards the leading edge.

2. An air movement fan according to claim 1 wherein the bumps extending from the leading and trailing edges merge smoothly with said surface of the blade to form valleys between adjacent protrusions.

3. An air movement fan according to any one of the preceding claims, wherein in plan view the protrusions on the leading edge describe a generally wavelike profile along the leading edge.

4. An air movement fan according to any one of the preceding claims, wherein the protrusions on the trailing edge describe, in plan view, a generally wavelike profile along the trailing edge

5. An air movement fan according to claim 1, wherein the offset is half the distance between adjacent protrusions.

6. An air movement fan according to claim 3 or 4, wherein the wavelike profile is sinusoidal, arcuate, rectangular or hyperbolically tangent.

7. An air movement fan according to any one of the preceding claims, wherein the wavelength and/or the wave amplitude parameters of the protrusions is varied along the length of the fan blade.

8. An air movement fan according to claim 7, wherein the wavelength and/or the wave amplitude at any particular point on the fan blade is dependent on the chord of the fan blade.

9. An air movement fan according to any one of the preceding claims, wherein the fan is a unidirectional axial fan.

10. An air movement fan according to any one of claims 1-8, wherein the fan is a reversible bidirectional axial fan.

11. An air movement fan according to claim 10, wherein the blades are symmetrical in transverse cross-section.

12. An air movement fan according to any one of claims 1-11, wherein the parameters of the protrusions towards the outer tip of the blades are gradually smaller or are omitted.

13. An air movement fan according to any one of the preceding claims, wherein the parameters of the protrusions towards the hub are gradually smaller or are omitted.

14. An air movement fan according to any one of the preceding claims, wherein the protrusions of the trailing edge have a different waveform and parameters from the protrusions on the leading edge.

15. An air movement fan substantially as described herein with reference to and as illustrated in the accompanying drawings.

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