(12) UK Patent Application (19) GB (11) 2486470 (13) A

(43) Date of A Publication 20.06.2012

(21) Application No: 1021349.4

(22) Date of Filing: 16.12.2010

(71) Applicant(s):
Flakt Woods Limited
(Incorporated in the United Kingdom)
Axial Way, Cuckoo Farm Business Park,
COLCHESTER, Essex, CO4 5ZD, United Kingdom

(72) Inventor(s):
Geoff Sheard
Dominique Revillot
Alain Godichon

(74) Agent and/or Address for Service:
Jensen & Son
366-368 Old Street, LONDON, EC1V 9LT,
United Kingdom

(51) INT CL:
F04D 29/68 (2006.01) *F04D 29/38* (2006.01)

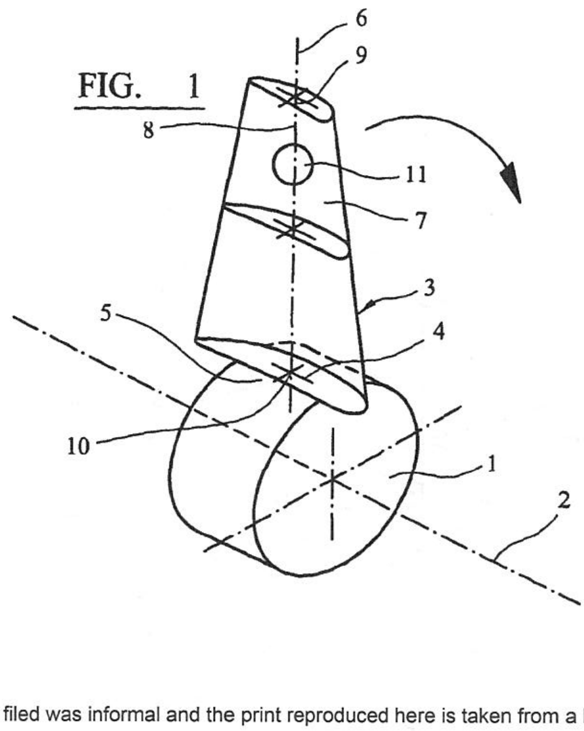
(56) Documents Cited:
GB 2093126 A
DE 029522190 U1
US 5232344 A
US 20090324406 A1
EP 1754886 A1
US 6155789 A
US 2828941 A
US 20070081894 A1

(58) Field of Search:
INT CL **F01D, F03D, F04D**
Other: **EPODOC, WPI**

(54) Title of the Invention: **Axial air movement fans**
Abstract Title: **Fan blade with oscillating damping mass**

(57) An axial fan comprises a hub 1 with a plurality of elongate fan blades 3 extending outwardly there from. Each blade 3 includes at least one damping mass 11 secured to the blade. The mass can oscillate relative to the blade in response to oscillatory flexing thereof to damp the flexing. The damping mass may be located within a hollow part of the blade. The mass may be attached to the blade a supporting wire 8 which is secured at its ends 9, 10 to the blade. The mass may be attached to the blade by a resilient bush or bushes. A resilient plate may be located within the blade, and secured to the blade at one end to form a cantilever. The mass may be attached to the plate, or the plate may itself be the mass. The mass may instead be attached to the outside of the blade.

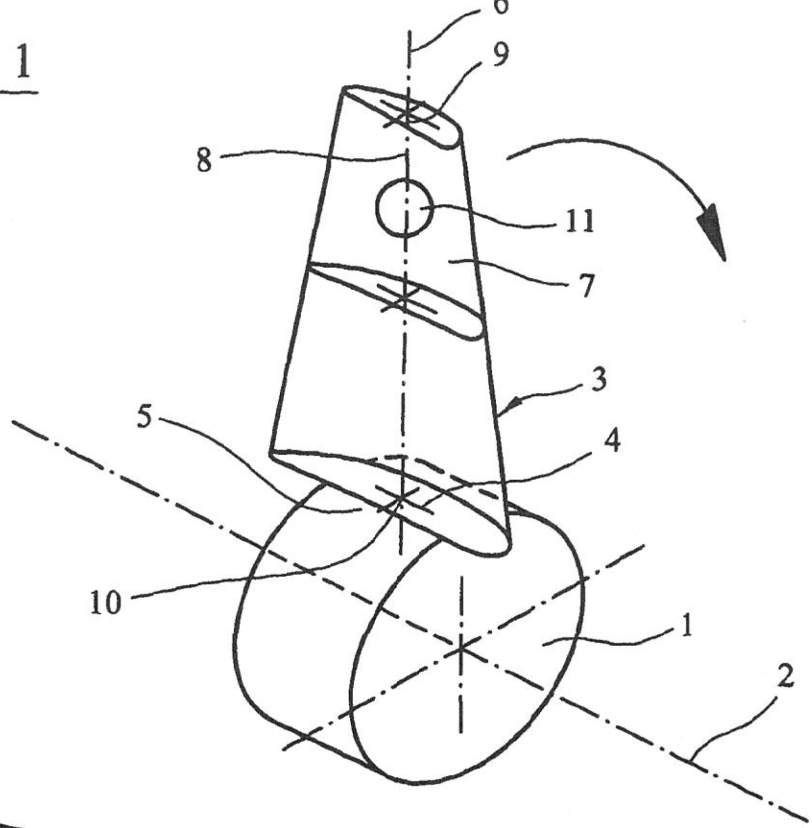
FIG. 1



GB 2486470 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 1



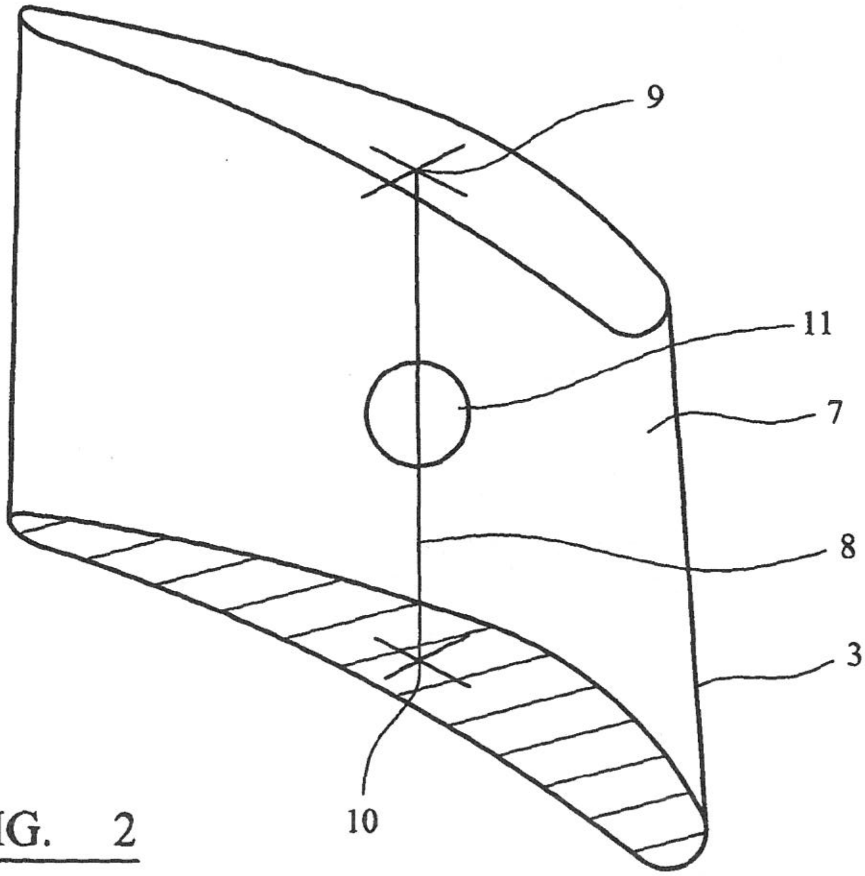


FIG. 2

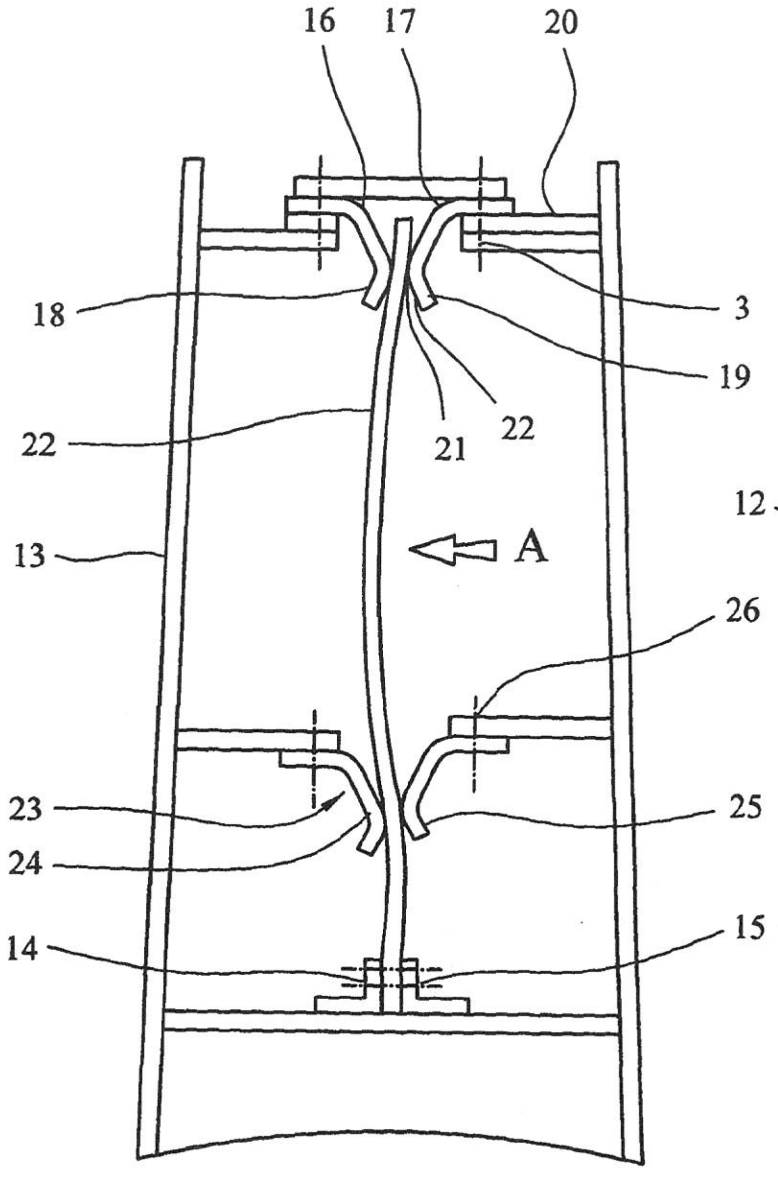


FIG. 3a

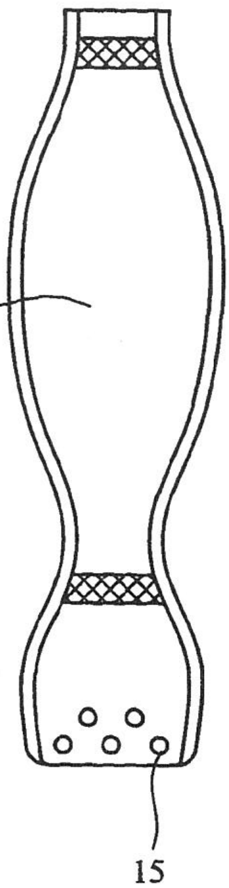


FIG. 3b

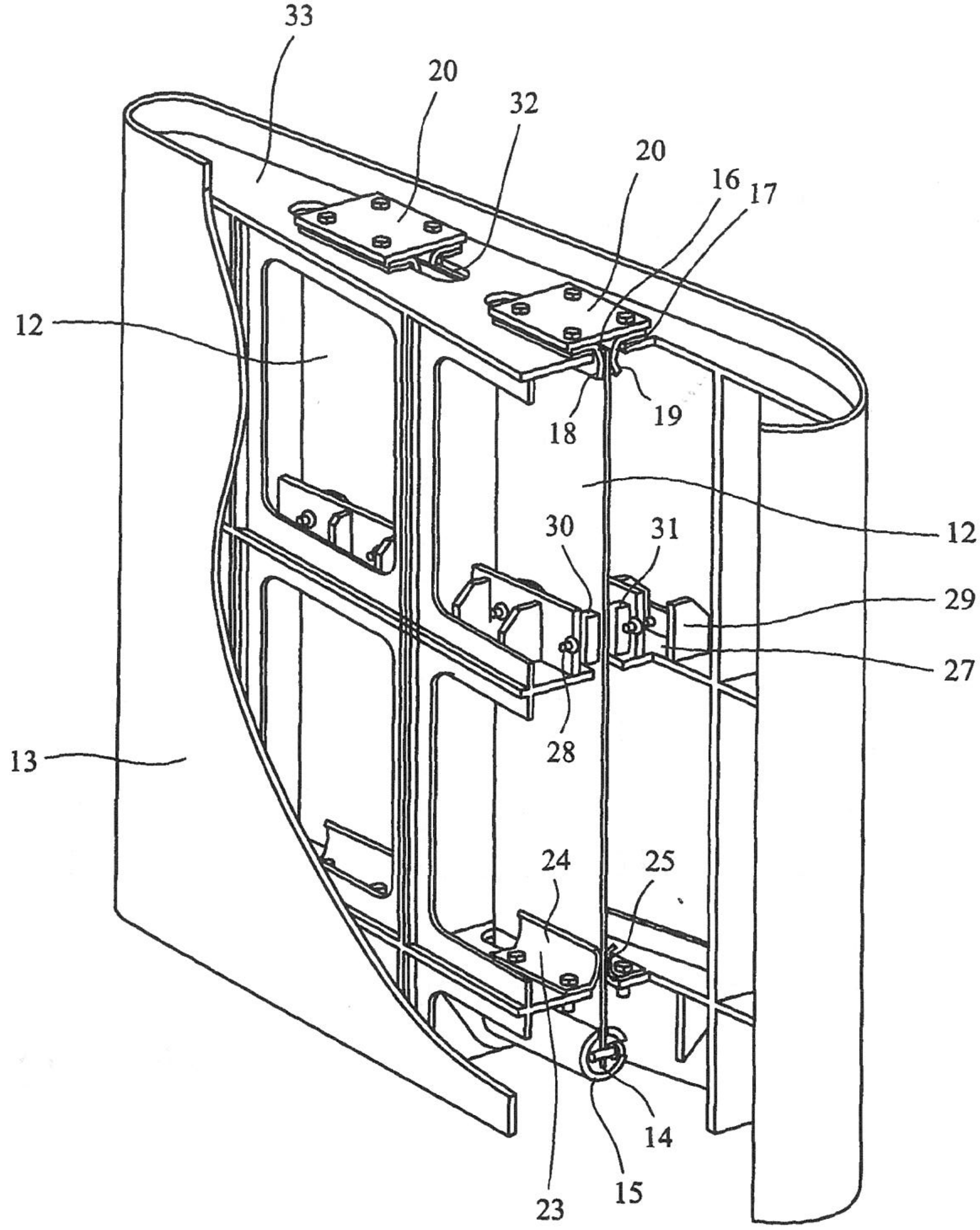


FIG. 4

Axial air movement fans

The present invention relates to axial air movement fans comprising a plurality of elongate fan blades disposed about a hub so as to extend in a generally radial direction.

Each fan blade therefore constitutes a cantilever secured to the hub and extending outwardly to the outer free end of the blade. The fan blades are elongate and typically placed at an angle to the circumferential plane of the axis of rotation and may have an aerofoil type cross-section to drive air across the fan. In cross-section, the fan blades have a major axis and a minor axis. In operation, when driving air, the fan blades are subject to air pressure and further forces caused by buffeting and turbulence of the air passing through the fan. These forces are transmitted to the hub as a cyclical bending moment through the root of the fan blade which is secured to the hub. The blades thus tend to bend about the major axis and the stress concentration at this point can lead to cracking and failure of the blade.

The normal operating forces are exacerbated if the vibratory loads on the blade are generated at the natural frequency of oscillation of the cantilevered blade. This can cause a permanent oscillation or vibration about the major axis of the blade at its root which can lead to premature and catastrophic failure of the blade..

The present invention seeks to provide a solution to this problem.

According to the present invention there is provided an air movement fan comprising a hub with a plurality of elongate fan blades extending generally radially outwardly therefrom, each blade including at least one damping mass secured to the fan in such a way as to enable the mass to oscillate relative to the fan blade in response to oscillatory flexing of the fan blade in a first plane, thereby to damp the flexing of the fan blade.

Preferably, each fan blade is at least partially hollow and the damping mass is located within the hollow part. In a preferred embodiment, the mass is secured to a supporting wire intermediate the length thereof, the supporting wire extending in the radial direction and its free ends being secured to the blade. In this way, the mass is constrained against radial movement caused by centrifugal force, apart from a slight resilient extension of the part of the wire between the mass and the radially innermost fastening, but is permitted a degree of lateral resilient movement to enable the mass to oscillate.

Although only one mass is shown in this embodiment, it will be understood that two separate masses may be located in the hollow space in the blade and these two masses may be tuned to be responsive to different frequencies.

In an alterantive embodiment, the damping mass comprises a plate secured at its radially innermost edge to the fan blade, its radially outermost end remote from said secured end being held in a guide device to constrain its movement in a controlled manner when the plate is oscillating. Preferably, the guide device comprises two members between faces of which said outermost end is clamped so as to be constrained against lateral movement but is able to pivot relative to the members, in which case. said faces may be curved so that the contact between the members and the plate is a line contact.

In one form, a resilient damping mass is located between each of the two members and the plate.

Preferably, a further guide device is located between the secured inner end of the plate and the first guide device, which further device may be located closer to the secured end than the outermost end.

Preferably, the further guide device comprises two members between faces of which an intermediate part of the plate is clamped so as to be constrained against lateral movement but is able to pivot relative to the members, in which case, said faces may be curved so that the contact between the members and the plate is a line contact.

Furthermore, a resilient damping mass may be located between each of the two members and the plate.

In a preferred embodiment, the cross-sectional area of the plate varies along its length to give a desired form of flexure.

A plurality of said plates may be provided in each fan blade.

A preferred embodiment of the present invention will now be described by way of example with reference to the accompanying informal sketch in which:
Figure 1 shows a schematic view of one blade of an air movement fan,
Figure 2 shows a schematic cross-sectional view showing the hollow interior of the fan blade
Figures 3a and 3b show a schematic arrangement in which the mass is formed by a plate, and
Figure 4 shows an embodiment in which a plurality of plates are provided.

Figure 1 shows a hub 1 of an axial fan mounted for rotation about an axis 2. A plurality of elongate fan blades, only one of which is shown as reference 3, equi-distantly disposed about the periphery of the hub and secured thereto so as to extend in a generally radial direction. As shown, the fan blade consists of an elongate member extending generally radially and is secured at its root to the hub at a slight angle to the plane of rotation of the hub. The fan has in cross-section a major axis 4 and a minor axis 5. It also has a radially extending longitudinal main axis 6.

Adjacent to its outer end, the fan blade has a hollow section 7 which contains a mass-spring system. The system consists of a mass 11, which may be formed of lead, which is suspended on a wire 8 intermediate the length thereof. The wire extends along the axis 6 of the blade 3 and is secured to the blade at its ends, references 9 and 10. The mass is thus constrained by the wire against movement in the radial direction caused by centrifugal force apart from a slight resilient extension of the part of the wire between the mass and the radially innermost fastening, but is permitted a degree of lateral movement against the resilience of the wire. It is envisaged that some degree of damping of the movement of the mass may be provided, which may be accomplished by means of a resilient damper such as a rubber bushing. The weight of the mass, the resilience of the wire and the initial tension in the wire is calculated to permit the mass to oscillate in response to vibratory movement of the blade at its first natural frequency. The fan blade acts as a cantilever and if an exciting force caused by turbulent airflow over the fan blade is present at the first natural frequency of the fan blade, permanent oscillation at the natural frequency may occur and this vibratory movement is opposed and dampened by the corresponding transverse oscillations of the mass, which responds to the oscillation of the fan blade and serves to damp out the induced oscillations in the fan blade. In this way, the stresses in the blade, particularly at the root of the blade, which could lead to early failure of the blade, are substantially reduced.

It is desirable for the mass to be located as far towards the outer tip of the fan blade as possible as this reduces the size of the mass needed. Although shown as a mass suspended on a wire, it is conceivable that the mass may be supported on a synthetic rubber bushing system designed to restrain the mass against movement in a radial direction but to move in a controlled resilient manner in a direction normal to the major axis of the blade. Although only one mass is shown in this embodiment, it will be understood that two separate masses may be located in the hollow space in the blade and these two masses may be tuned to be responsive to different frequencies.

The mass may be formed by a flexible plate in the form of a cantilever in the hollow space, preferably being secured to the radially outermost face of the hollow space so as to extend generally radially inwardly. The plate may have a mass concentrated at its free end.

Figures 3a, 3b and 4 show an alternative embodiment, in which Figure 3a shows a cross-section through the hollow part of a fan blade viewed in the circumferential direction showing a flexible plate, Figure 3b shows a view of the flexible plate in the direction of the arrow A in Figure 3a, and Figure 4 shows a part sectional perspective view of an arrangement in which two plates are located in the interior of the fan blade.

Figure 3a shows a flexible plate 12 located in the interior of a fan blade casing 13. The radially innermost edge 14 of the plate 12 is secured by bolts in a mounting 15 secured to the main body of the fan blade. At its radially outermost end 16, the plate 12 is located in a guide device 17 which has a pair of opposing clamping members 18 and 19 between which the plate is located. The locating members are secured by bolts to a mounting bracket 20 secured to the main body of the fan blade13. The surfaces 21, 22 of the clamping members facing and engaging with the plate 12 are curved or arcuate so that there is only a single line contact between the clamping members and the plate on a line a short distance from the outer edge 14 of the plate. In this way, the outer part of the plate 12 is able to pivot slightly when the plate curves due to oscillatory forces and is also able to accommodate the slight change in length, that is longitudinal extent, of the plate due to the curvature it adopts when being deflected. In an alternative embodiment (not shown), resilient means such as rubber bushing is positioned between the surfaces of the clamping members and the plate, the resilient means having sufficient flexibility to accommodate the required slight movement of the end of the plate.

Additionally, a further guide 23 may be positioned intermediate the ends of the plate 12 to control the amount of movement of the plate in this mid-position. As shown, this further guide device is located approximately one quarter of the way from the fixed end of the plate towards the free end, but its position may be varied to give the characteristics desired. In a similar manner to the first guide device, the further guide device has two clamping members 24, 25 which engage the plate 12 on a line contact. The two clamping members are again bolted to a mount 26 secured to the main body of the fan blade. It is also envisaged that resilient damping means may be disposed between the clamping faces of the members 24 and 25 and the plate 12. In this way, when the plate flexes due to oscillatory forces, its assumes a shallow S shape with the part below the lower guide 23 curving in one direction and the part between the two guides 17 and 23 curving in the opposite direction. By appropriate positioning of the further guide device it is possible to tune the frequency and amount by which the plate deflects when subjected to oscillatory forces.

Referring now to Figure 3b, it can be seen that the cross-sectional area of the plate can be varied by varying its width, or metal thickness, to give the desired damping characteristics.

Turning now to Figure 4, there is shown a part sectional view of a fan blade 13 having a hollow interior containing two damping plates 12, both in accordance with the present invention. In this embodiment the two damping plates 12 are identical and only one will be described for convenience, although it will be appreciated that the two devices may be of different size, thickness and shape to achieve the damping characteristics required.

In this description of Figure 4 like parts will bear like references to those shown in Figure 3a. The plate 12 is secured in a mounting bracket 15 in turn secured to the main body of the fan blade 13. At its radially outermost end 16, the plate is located in a guide device 17 as described in connection with Figure 3a. Just radially outwardly of the mounting bracket 15, a further guide 23 is located, although, compared to the embodiment of Figure 3a, the clamping members 24, 25 are directed in the radially outward direction rather than radially inwardly.

In addition, in this embodiment, a further damping means 27 is located generally intermediate the guide devices 17 and 23. The damping means 27 consists of brackets 28, 29 secured to the main body of the fan blade 13 and each carrying a pair of resilient damping masses 31, 32 formed by rubber bushes, which abut the faces of the plate 12 and are designed to limit and damp the oscillatory movement of the plate. Although shown as abutting the plate, it will be understood that in certain circumstances these resilient masses 31, 32 may be spaced from the surface of the plate in the static position.

It can be seen that the fan blade 13 contains two identical plates 12 but it is envisaged that these plates may differ in size and thickness, and response rate to give the desired damping characteristics. To increase flexibility, the mountings 24 for the plates 12 are located in elongate slots 32 in a subframe 33 which is itself secured to the fan blade. In this way, the whole damping assembly can be built as a subassembly with varying widths of plate for easy incorporation into the fan blade on final assembly.

For relatively small sizes of fan blade, it may not be practical to locate the mass within the blade, in which case the mass may be suspended on the outside of the blade with the wire being secured to limbs extending outwardly from the blade face. It is possible that two masses may be provided, one on each face of the blade. It is also possible for the mass or masses to be secured directly to the blade by means of a resilient mounting bush formed of synthetic rubber.

In certain installations, under certain conditions, a higher frequency harmonic may be generated in the fan blade causing the blades to oscillate about its longitudinal axis 6. To counter this, a smaller mass may be secured in the hollow section of the blade in such a way that it is constrained against radial movement but is able to oscillate about the longitudinal axis 6 of the blade. In such an arrangement, it may be preferable for the mass to be a disc like structure with its mass concentrated at the periphery.

In a further embodiment, the mass may be formed by an outer skin section bonded to the rest of the blade by means of a resilient bushing and having the same profile as the fan blade so as not to adversely effect the flow of air past the blade.

CLAIMS

1. An axial air movement fan comprising a hub with a plurality of elongate fan blades extending generally radially outwardly therefrom, each blade including at least one damping mass secured to the fan in such a way as to enable the mass to oscillate relative to the fan blade in response to oscillatory flexing of the fan blade in a first plane, thereby to damp the flexing of the fan blade.

2. A fan as claimed in claim 1, wherein each fan blade is at least partially hollow and the damping mass is located within the hollow part.

3. A fan as claimed in claim 1 or 2, wherein the mass is secured to a supporting wire intermediate the length thereof, the supporting wire extending in the radial direction and being secured to the blade at its ends, so that the mass is constrained against radial movement caused by centrifugal force but is permitted a degree of lateral resilient movement to enable the mass to oscillate laterally.

4. A fan as claimed in claim 1, 2 or 3, wherein the mass is secured to the fan blade through the medium of a resilient bush or bushes.

5. A fan as claimed in claim 1 or 2, wherein a resilient plate is located in the hollow space, one edge of which is secured to the blade to provide a cantilever, the mass being provided by the plate, or being at least partially formed by a mass on a free end of the plate.

6. A fan as clamed in claim 5, wherein the plate is secured to the radially outermost face of the hollow space.

7. A fan as claimed in claim 5, wherein the plate is secured at its radially innermost edge to the fan blade, its radially outermost end remote from said secured end being held in a guide device to constrain its movement in a controlled manner when the plate is oscillating.

8. A fan as claimed in claim 7 wherein the guide device comprises two members between faces of which said outermost end is clamped so as to be constrained against lateral movement but is able to pivot relative to the members.

9. A fan as claimed in claim 8 wherein said faces are curved so that the contact between the members and the plate is a line contact.

10. A fan as claimed in claim 8 wherein a resilient damping mass is located between each of the two members and the plate.

11. A fan according to any one of claims 7 to 10 wherein a further guide device is located between the secured inner end of the plate and the first guide device.

12. A fan according to claim 11 wherein the further guide device is located closer to the secured end than the outermost end.

13. A fan according to claims 11 or 12 wherein the further guide device comprises two members between faces of which an intermediate part of the plate is clamped so as to be constrained against lateral movement but is able to pivot relative to the members.

14. A fan as claimed in claim 13 wherein said faces are curved so that the contact between the members and the plate is a line contact.

15. A fan as claimed in claim 11 or 12 wherein a resilient damping mass is located between each of the two members and the plate.

16. A fan as claimed in any one of claims 7 to 15, wherein the cross-sectional area of the plate varies along its length to give a desired form of flexure.

17. A fan according to any one of claims 7 to 16 wherein a plurality of said plates are provided.

18. A fan as claimed in claim 1, wherein the mass is secured on the outside of the fan blade.

19. A fan as claimed in any one of the preceding claims wherein the mass comprises two separate weights.

20. A fan as claimed in any one of the preceding claims, including a further mass adapted to dampen a higher frequency harmonic by oscillatory movement about the longitudinal axis of the blade.

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