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(54) **Warped rotor blade composed of two parts joined together**

(57) A rotor blade (1) having a warping angle ( $\alpha$ ) variable in a predefined manner from its base to its end is described, the said blade being formed by means of joining together a nose piece (2) and a tail piece (3) designed to form, when joined together, a given aerodynamic profile with cross sections having predefined

shapes, in which the said tail piece (3) is hollow and has substantially a shape terminating in an open "V", the free ends (3m, 3n) of the sides of which are designed to be joined to the end part (2t) of the said nose piece (2).

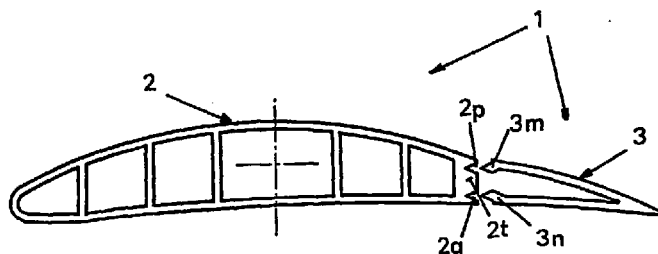


FIG. 1

## Description

**[0001]** The present invention relates to the technological field of propellers, fans or more generally to twin-blade or multi-blade rotors which are used for aeronautical applications or for ventilation purposes since they produce with their movement an axial air flow parallel to their axis of rotation.

**[0002]** More particularly, the invention relates to a blade suitable for being fixed to the hub of a rotor.

**[0003]** As persons skilled in the art know, sections of a blade located at different radial distances from the axis of the hub, i.e. the axis of rotation, have different tangential translation speeds for the same angular speed of rotation of the rotor.

**[0004]** Moreover, for geometrical and structural reasons, the net thrust area of a blade normally increases in the direction from the end of said blade towards the hub.

**[0005]** In order to obtain a flow weight per unit of area of the disc traced by the blades of a rotor having a uniform value over the entire area of the said disc, so as to prevent turbulence or associated energy losses, it is required to "warp" the blades, imparting to them a twist about their longitudinal axis with different angles of torsion, from one section to another, which therefore vary in a predefined manner and which, starting from zero at the end of the blade, increase in the direction towards the hub.

**[0006]** For certain applications such as, for example, large-diameter multi-blade rotors for fans, intended for heat exchangers or cooling towers, it has been noted how, in order to obtain the uniform flow described above, it is required to produce warping of the blades with amplitudes of the warping angle which vary in accordance with curves of the second order (parabolas, hyperbolas).

**[0007]** In order to obtain such warping for fans with a diameter of up to 12 m, applying torsional mechanical stresses to the blades produces difficulties and complications such that, in these cases, it is preferred to produce warping with a linear variation in the associated angle, thus accepting a *priori* a substantial reduction in the efficiency.

**[0008]** In the cases where a substantially higher cost is acceptable, blades made of glass-fibre reinforced plastic are used, it being possible to produce said blades with parabolic or hyperbolic warping during manufacture thereof.

**[0009]** In order to attempt to solve the problem of creating warped rotor blades which are low-cost, i.e. made of aluminium, according to the present state of the art blades are made composed of a nose piece and a tail piece, said parts extending linearly along the whole longitudinal extension of the said blades and being joined together after undergoing varied twisting. These two parts are formed from box-type extruded sections, i.e. having the outline of their profile closed

perimetrically, with the tail profile having a cross section covering a small area compared to that of the nose profile.

**[0010]** The abovementioned "box-type" geometrical form ensures that the torsional strength modulus of the tail piece, despite the small area of its cross section, in any case has a significant value and in particular is almost constant along the whole longitudinal extension of the said part: these two factors in combination firstly make it extremely difficult to perform non-linear warping of the tail piece and secondly result in the contours of the tail piece after warping - especially in its sections where the warping angle is more accentuated - being such that they cannot be precisely matched with those of the end of the nose profile onto which they are to be fixed.

**[0011]** This results in the need to perform major adjustments in order to join the two parts together, moreover with results which are not satisfactory from the point of view of the quality of workmanship and the performance achieved.

**[0012]** In order to overcome the abovementioned drawbacks, the inventor of the present invention has devised a rotor blade which is obtained by means of two parts, i.e. a nose piece and a tail piece, joined together and in which the cross-sectional shape of the tail piece is such that it satisfies the requirements with regard to lift and static thrust, but has a limited torsional and flexural strength, thus being suitable for deformation with warping angles which are variable in accordance with a desired non-linear pattern in the direction of the longitudinal axis of the said blade, without its external edges assuming contours which cannot be matched with those of the end part of the nose piece onto which it is to be fixed.

**[0013]** This result is obtained by forming the said tail piece from a section having a cross section terminating in the form of an open "V", it being understood by this that the said cross section may have globally this form, as in the example which will be described below.

**[0014]** The present invention in fact relates to a rotor blade as described in the preamble of the accompanying Claim 1, characterized by the characterizing part of the same claim.

**[0015]** An example of embodiment which is to be regarded as non-limiting and not binding with regard to other embodiments which can be obtained by changing the form of its parts and the profile of their sections, will now be described in greater detail.

**[0016]** During the description reference will also be made to the accompanying drawings in which:

- Figure 1 shows an exploded view of the cross section of a preferred embodiment of a blade according to the invention (composed of two parts) along the region of its free end;
- Figure 2 shows an exploded view of the cross section of the blade according to Figure 1 along its mid-

dle section;

- Figure 3 shows an exploded view of the cross section of the blade according to Figures 1 and 2 in the region of its base, i.e. in the vicinity of its point of attachment to the hub;
- Figure 4 shows a cross-sectional view of the blade along its middle section with the two parts which form it being assembled.

**[0017]** With reference to Figures 1, 2 and 3, it can be seen how a blade 1 according to the invention is composed of a nose piece 2 and a tail piece 3 which can be assembled together: the tail piece 3 is formed from a hollow extruded section in the form of an open "V" with a desired thickness of its walls.

**[0018]** The free ends 3m, 3n of the tail piece are shaped so that they have a profile matching two recesses 2p, 2q formed on the end part 2t of the nose piece 2 which is formed from an extruded section of the box type, i.e. with a closed contour.

**[0019]** After the two parts 2, 3 forming the blade 1 have undergone warping in the desired manner, they may be joined together: the low torsional and flexural strength of the two sides of the open "V" forming the tail piece 3 facilitates the said warping and in particular, also during the assembly stage, allows warping thereof, if necessary, to be modified slightly in a suitable manner, section by section, so as to achieve perfect mating of the aligned edges of the two parts 2, 3 assembled together as shown in Figure 4.

**[0020]** The invention thus provides a blade 1 with non-linear warping (see progression of warping angle  $\alpha$  in Figures 1 to 3) which can be achieved by means of simple operations and using extruded sections, preferably made of aluminium, having a low cost, thus achieving the predefined objects of the inventor.

**[0021]** The two parts 2, 3, after assembly, may be fixed using known techniques such as, for example, riveting, welding or gluing using special structural adhesives known to persons skilled in the art.

**[0022]** It is obvious that the shape of the two parts, i.e. nose piece and tail piece, constituting a rotor blade according to the invention may be modified with respect to the example illustrated hitherto depending on design requirements and the type of aerodynamic profile which is to be obtained.

**[0023]** Constructional forms thus obtained nevertheless fall within the protective scope of the present application provided that they are based on the concepts expressed in the accompanying Claim 1.

## Claims

1. Rotor blade (1) having a warping angle ( $\alpha$ ) variable in a predefined manner from its base to its end, the said blade being formed by means of joining together a nose piece (2) and a tail piece (3) designed to form, when joined together, a given

aerodynamic profile with cross sections having predefined shapes, characterized in that the said tail piece (3) is hollow and has substantially a shape terminating in an open "V", the free ends (3m, 3n) of the sides of which are designed to be joined to the end part (2t) of the said nose piece (2).

2. Rotor blade according to Claim 1, in which the said free ends (3m, 3n) of the tail piece (3) terminating in an open "V" have a profile matching recesses (2p, 2q) formed along the whole length of the blade (1) on the said end part (2t) of the said nose piece (2).
3. Rotor blade according to one of the preceding claims, in which the said nose piece (2) and the said tail piece (3) are fixed together by means of structural adhesives.
4. Rotor blade according to one of Claims 1 or 2, in which the said nose piece (2) and the said tail piece (3) are fixed together by means of riveting.
5. Rotor blade according to one of Claims 1 or 2, in which the said nose piece (2) and the said tail piece (3) are fixed together by means of welding.
6. Rotor blade according to one of the preceding claims, characterized in that both the said nose piece (2) and the said tail piece (3) which form it are extruded sections made of aluminium.

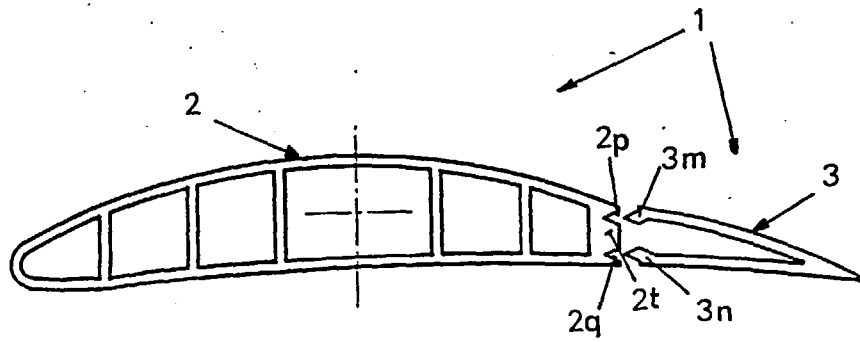


FIG. 1

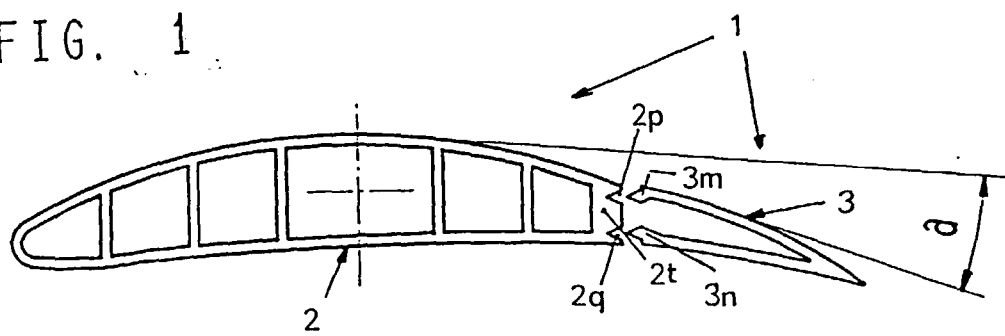


FIG. 2

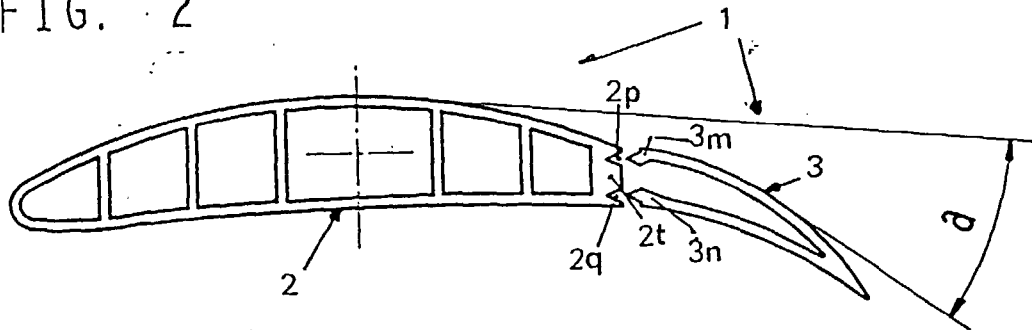


FIG. 3

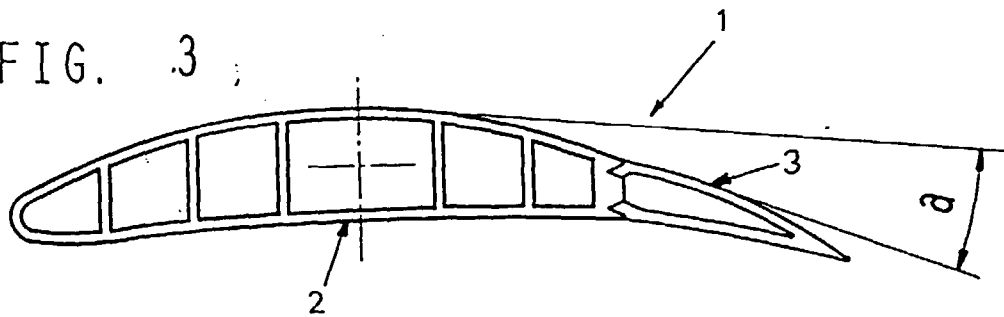


FIG. 4



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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                         |                                  |                                              |
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| <p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone<br/> Y : particularly relevant if combined with another document of the same category<br/> A : technological background<br/> O : non-written disclosure<br/> P : intermediate document</p> <p>T : theory or principle underlying the invention<br/> E : earlier patent document, but published on, or after the filing date<br/> D : document cited in the application<br/> L : document cited for other reasons<br/> &amp; : member of the same patent family, corresponding document</p> |                                                                                                                         |                                  |                                              |

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