Aug. 8, 1961 R. S. RADCLIFFE 2,995,191

FAN APPARATUS

Filed April 21, 1958

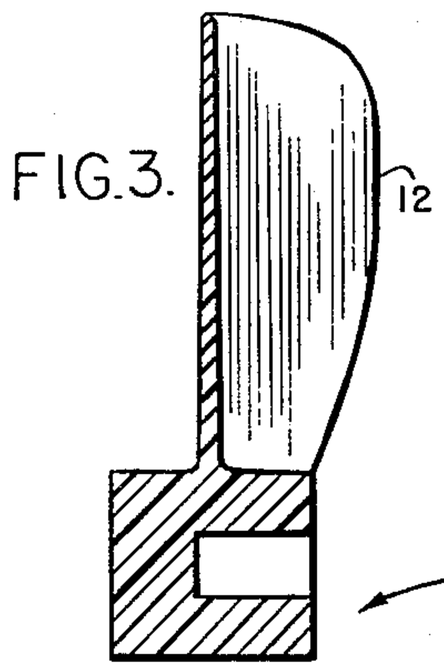

FIG. 3.

FIG. 1.

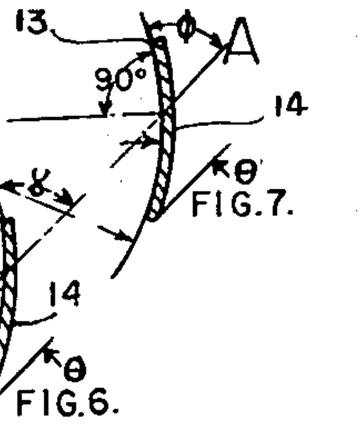

FIG. 7. FIG. 6. FIG. 5. FIG. 4.

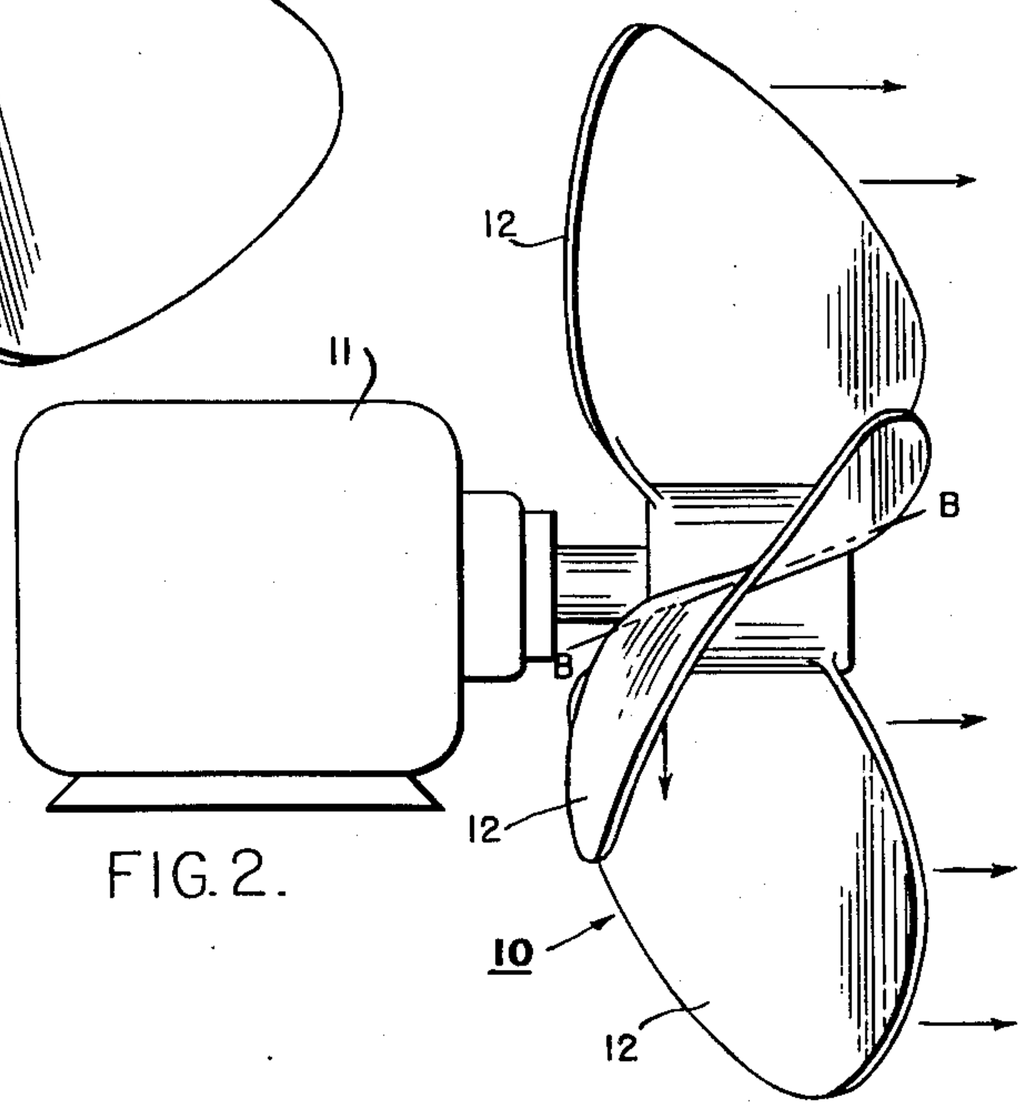

FIG. 2.

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2,995,191

Patented Aug. 8, 1961

2,995,191

FAN APPARATUS

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Filed Apr. 21, 1958, Ser. No. 729,583

6 Claims. (Cl. 170—159)

This invention relates to propeller fan apparatus and more particularly to blade configurations for propeller fans constructed of molded plastic, or other similar materials, that are subject to distortion under centrifugal forces.

The efficiency with which a fan operates depends not only on the aerodynamic characteristics of the fan blades, but also on their freedom from unbalanced forces that cause deformation of the preferred blade contours. Unless each blade portion is carefully disposed relative the other and in relation to the axis of rotation it is possible that centrifugal forces will deform the blade, thus causing a loss of aerodynamic efficiency.

In the construction of fan blades the attainment of both aerodynamic efficiency and freedom from distortion presents a problem. More specifically, the problem involves the forming of fan blades from moldable plastic when permanently deforms at a slow, gradual rate when strained by forces encountered during rotation of the fan. This phenomenon is referred to as "cold flow," and is characteristic of such materials as polystyrene, polyethylene, and acetal resin plastics that are, otherwise, well suited for forming molded, one piece fans.

The present invention provides for the molding of plastic fan blades in a shape that aligns the majority of the longitudinal blade segments radially and perpendicularly with respect to the axis of rotation in order to free the major portion of the blade from deforming centrifugal forces. In addition, a minor or trailing edge portion of the blade is shaped, as will be described in greater detail below, in a manner which results in greater aerodynamic efficiency than a blade constructed entirely of longitudinal segements that are radial and perpendicular to the rotational axis.

The various objects, features and advantages of the invention will appear more fully from the detailed description which follows, taken in connection with the accompanying drawings, forming a part of this application, in which:

FIG. 1 is a front view of the air exit side of an integrally molded, multi-blade fan having blades constructed according to the invention;

FIG. 2 is a side view of the fan of FIG. 1 mounted on the shaft extension of an electric motor;

FIG. 3 is a sectional view taken along radial line III—III of FIG. 1; and

FIGS. 4 through 7 are sectional views taken, respectively, along lines IV—IV through VII—VII of FIG. 1, and normal to line A—A which is radial and perpendicular to the rotational axis.

The fan apparatus embodying the invention comprises a multi-blade fan having a hub **10**, mounted for rotation, as shown in FIG. 2, on the shaft extension of a motor **11**. Three similar fan blades **12**, formed from moldable plastic material, are equally spaced about the hub **10**, and are integral therewith. Since each blade **12** is structurally representative of the other, only one blade will be described in detail.

The blade **12** comrises a major portion **13** which includes the leading edge, and a minor portion **14** which includes the trailing edge. The major portion **13** has a surface generated by a staight line generatrix which remains radial and perpendicular to the rotational axis as it moves from the leading edge to a line of jointure

A—A between respective contiguous surfaces of the major and minor portions **13** and **14** (see FIG. 1). Inasmuch as the major portion **13** of the blade has considerably greater surface area than the minor portion **14**, the line of jointure A—A between the two portions is closer to the trailing edge of the blade than to the leading edge of the blade. The major portion **13** can also be described as comprising a multiplicity of axially incremental segments wherein the blade surfaces are aligned, as in FIG. 3, radially and perpendicularly with respect to the axis of rotation. Thus, the centrifugal forces which ensue from operation of the fan tend only to lengthen the blade **12**, rather than to "feather" or reorient the blade so that it propels less air, as in the case of ordinary fan blades.

The "feathering" experienced by ordinary fan blades is not unlike the untwisting action of a helical spring when placed in tension. Parts tend to align themselves in the direction of the applied force, and for this reason, prealignment of longitudinal blade segments in the direction of the expected centrifugal forces avoids deformation of the blade surfaces.

Alignment of the blade surfaces with the direction of the centrifugal forces does not necessarily require the blade surfaces to be flat. Twisted working surfaces have long been recognized as a means for improving the aerodynamic efficiency of fan blades, and such surfaces are employed in the embodiment selected for illustrating this invention. As depicted in FIG. 2 by phantom line B, the generatrix follows a substantially straight line path along the surface of the hub **10** and yet generates a twisted working surface. However, it should be understood that a non-deforming surface could be generated by a straight line generatrix which moves through a curved path, rather than a straight path, on the surface of the hub **10**; provided, however, that the generatrix remains radial and perpendicular to the axis of rotation.

It has been found by test that large gains in aerodynamic efficiency can be obtained by departing from the previously described radial and perpendicular blade construction technique when forming the minor blade portion **14**, a relatively small area adjacent the trailing edge. Net gains in efficiency as high as twenty-five per cent over blades constructed entirely in the manner of the major blade portion **13** are effected, despite the losses from a small amount of cold flow distortion.

The minor blade portion **14** has a warped surface which is defined by the locus of arcuate lines that are tangent to the major blade portion **13** at line A—A and lying in planes normal to line A—A. Preferably, each arcuate line has a constant radius (*r* in FIGS. 4 through 7) and the radius of curvature is uniform for all of the lines. This preferred surface configuration of the minor blade portion **14** is illustrated in the drawings and can be alternatively defined as being generated by a constant radius, arcuate generatrix element which is maintained tangent to the surface of the major blade portion **13** at line A—A as the generatrix is moved along line A—A and maintained normal to the line A—A. In FIGS. 4 through 7 the character *r* also denotes the radius of curvature of such a generatrix element.

This minor blade portion **14** can also be envisioned, in its preferred form, as a longitudinal strip-like segment of a bent tube. As can be seen from a comparison of FIGS. 4 through 7, the surface of the minor blade portion **14**, when formed in the above described fashion, lies equidistantly spaced from an imaginary curved line C—C which corresponds to the axis of the bent tube from which the surface of the minor blade portion **14** is taken.

Where a twisted or helical surface is formed from radial and perpendicular elements, as is the major blade portion

13, the exit angles or any angles along the blade (such as angles α, β, γ, and ϕ along line A—A) increase as the distance from the axis of rotation increases; and it is the function of the minor blade portion 14 to reestablish the exit angles θ along the trailing edge of the blade to values that improve air moving efficiency. Stated another way, it is possible to obtain a uniform exit angle θ at the trailing edge of the blade, even though the blade surfaces at the line A—A make non-uniform angles with a plane of rotation therethrough; and this is accomplished by extending each portion along the curved trailing edge rearwardly until it makes the same angle at the trailing edge with a plane of rotation as does its neighboring trailing edge portion. For example, the blade surface of the major blade portion in FIG. 4 makes a much smaller angle (angle α) with the plane of rotation through line A—A than does the corresponding blade surface in FIG. 6 (angle γ); and yet their respective exit angles θ along the trailing edge are the same, because the trailing edge in FIG. 6 was extended rearwardly through a curved path a greater distance from line A—A than the trailing edge of FIG. 4.

In a 10¼ inch fan, constructed in accordance with the present invention, satisfactory aerodynamic performance plus unusual resistance to cold flow deformation were achieved by apportioning to the major and minor blade portions, respectively, 85% and 15% of the total surface area of each blade.

From the foregoing it can be seen that the invention provides for a warped minor portion 14 of the blade 12, adjacent the trailing edge, to be combined with a major blade portion 13 designed to be free from cold flow distortion. The resulting construction permits a unitary fan assembly of blades 12 and a hub 10 to be inexpensively manufactured of molded plastic without sacrificing aerodynamic efficiency.

While the invention has been shown in but one form, it will be obvious to those skilled in the art that it is not so lmited, but is susceptible of various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. A fan blade arranged for rotation about an axis, said blade comprising a major portion including a leading edge and a minor portion including a trailing edge, said major and minor blade portions being formed so that their respective contiguous surfaces are joined along a line which is radial and perpendicular to said axis, said major blade portion having a surface generated by a straight-line generatrix element which remains radial and perpendicular to said axis as it moves between said leading edge and said line, said minor blade portion having a surface generated by an arcuate generatrix element which remains tangent to said major blade portion at said line and normal to said line as it moves along said line.

2. A multi-blade fan arranged for rotation about an axis, each blade comprising a major portion including a leading edge and a minor portion including a trailing edge, said major and minor blade portions being integrally formed so that their respetcive contiguous surfaces are joined along a line which is radial and perpendicular to said axis, said line being closer to said trailing edge than to said leading edge, said major blade portion having a surface generated by a straight-line generatrix element which remains radial and perpendicular to said axis as it moves between said leading edge and said line, said minor blade portion having a surface generated by an arcuate generatrix element having a constant radius of curvature and which remains tangent to said major blade portion at said line and normal to said line as it moves along said line.

3. A multi-blade fan arranged for rotation about an axis, said blades being constructed of molded plastic material, each of said blades comprising a major portion including a leading edge and a minor portion including a trailing edge, said major and minor blade portions being integrally formed so that their respective contiguous surfaces are joined along a line which is radial and perpendicular to said axis, said line being closer to said trailing edge than to said leading edge, said major blade portion having a surface generated by a straight-line generatrix element which remains radial and perpendicular to said axis as it moves between said leading edge and said line, said minor blade portion having a surface generated by an arcuate generatrix element which remains tangent to said major blade portion at said line and normal to said line as it moves along said line.

4. A multi-blade fan arranged for rotation about an axis, said blades being constructed of molded plastic material, each of said blades comprising a major portion including a leading edge and a minor portion including a trailing edge, said major and minor blade portions being integrally formed so that their respective contiguous surfaces are joined along a line which is radial and perpendicular to said axis, said line being closer to said trailing edge than to said leading edge, said major blade portion having a surface generated by a straight-line generatrix element which remains radial and perpendicular to said axis as it moves between said leading edge and said line, said minor blade portion having a surface generated by and arcuate generatrix element which remains tangent to said major blade portion at said line and normal to said line as it moves along said line.

5. A multi-blade fan arranged for rotation about an axis, said blades being constructed of molded plastic material, each of said blades comprising a major portion including a leading edge and a minor portion including a trailing edge, said major and minor blade portions being integrally formed so that their respective surfaces are joined along a line of jointure which is radial and perpendicular to said axis, said line of jointure being closer to said trailing edge than said leading edge, said major blade portion having a surface generated by a straight-line generatrix element which remains radial and perpendicular to said axis as it moves between said leading edge and said line of jointure, said minor blade portion having a surface defined by the locus of arcuate lines, said arcuate lines being tangent to said major blade portion at the line of jointure and lying in planes normal to said line of jointure.

6. A multi-blade fan arranged for rotation about an axis, said blades being constructed of molded plastic material, each of said blades comprising a major portion including a leading edge and a minor portion including a trailing edge, said major and minor blade portions being integrally formed so that their respective surfaces are joined along a line of jointure which is radial and perpendicular to said axis, said line of jointure being closer to said trailing edge than said leading edge, said major blade portion having a surface generated by a straight-line generatrix element which remains radial and perpendicular to said axis as it moves between said leading edge and said line of jointure, said minor blade portion having a surface defined by the locus of arcuate lines of uniform radius, said arcuate lines being tangent to said major blade portion at the line of jointure and lying in planes normal to said line of jointure.

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