Nov. 25, 1958 E. W. RUNDLE 2,861,738

BLADES, GUIDE VANES AND THE LIKE FOR FANS TURBINES AND THE LIKE

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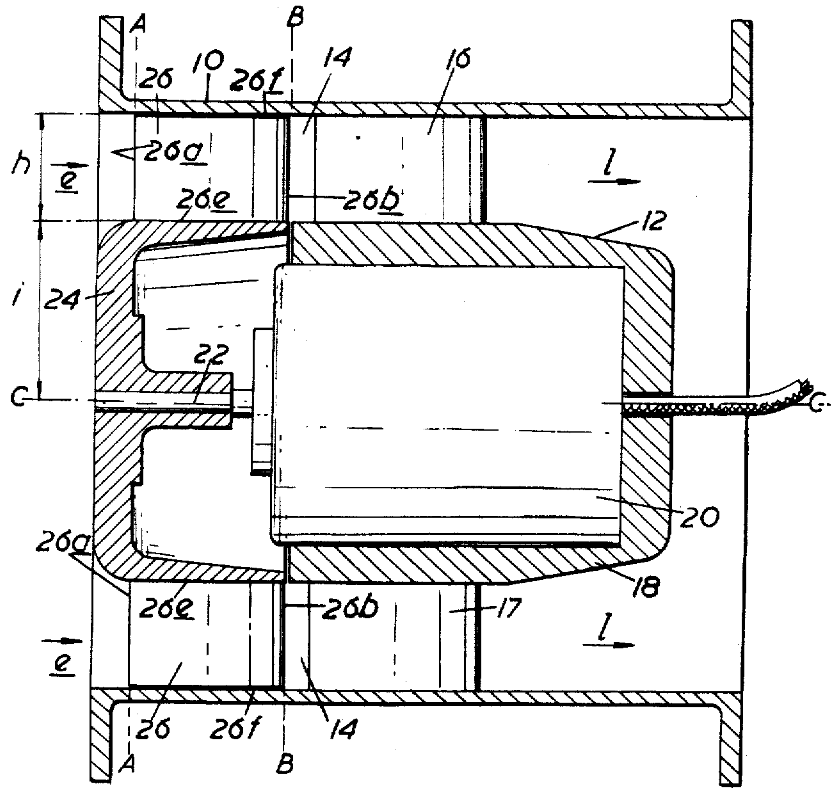
FIG. 1.



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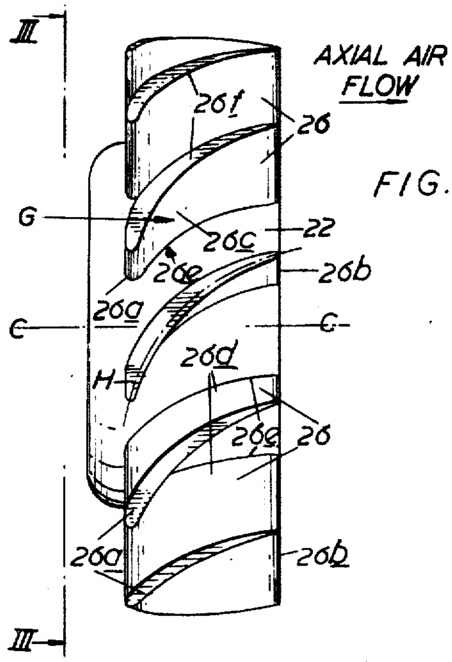

FIG. 2.

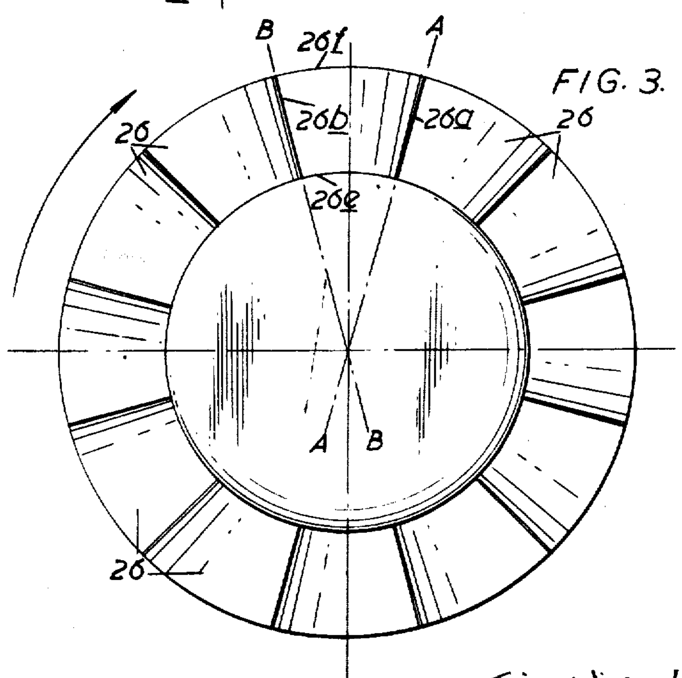

FIG. 3.

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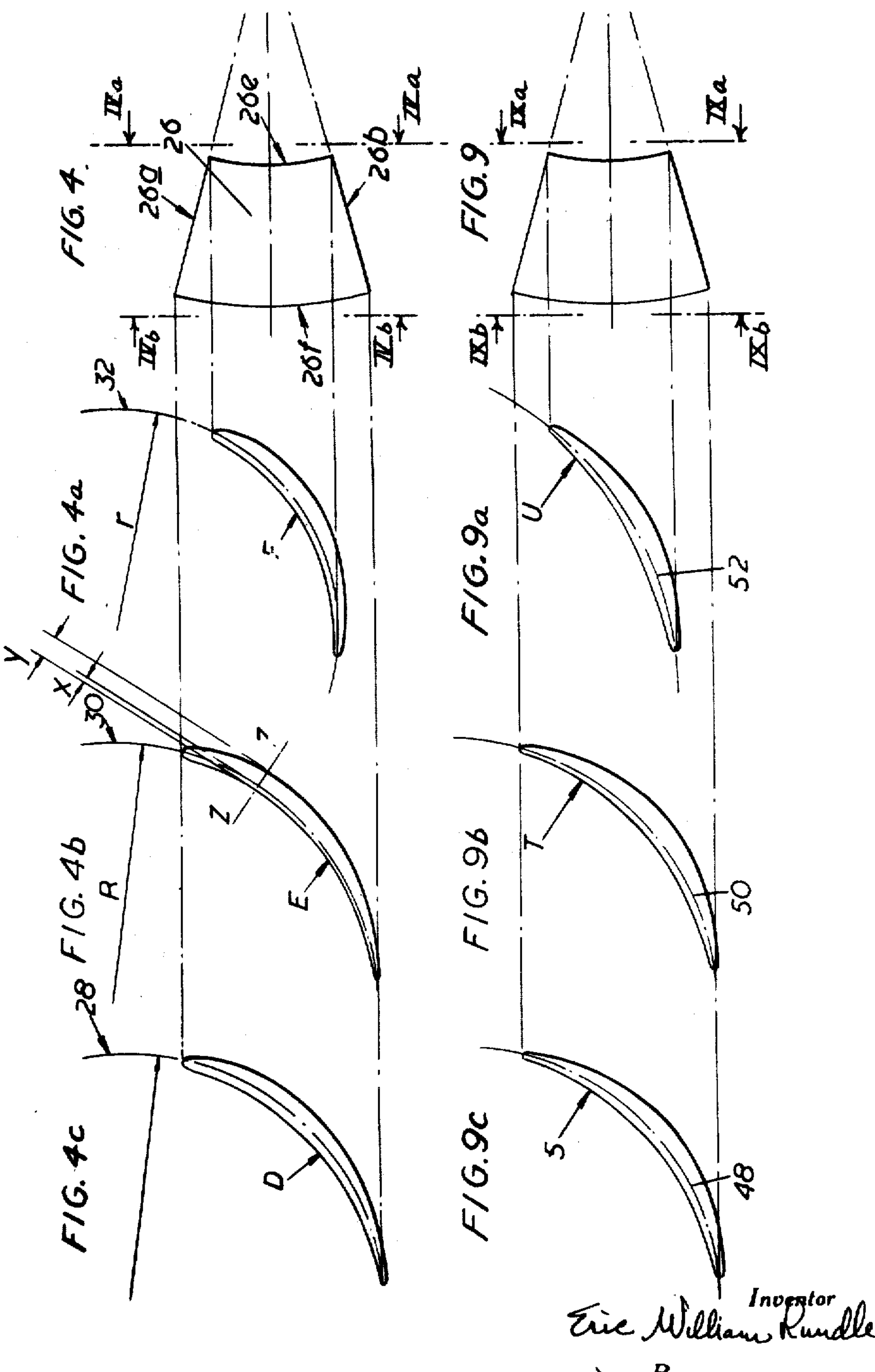

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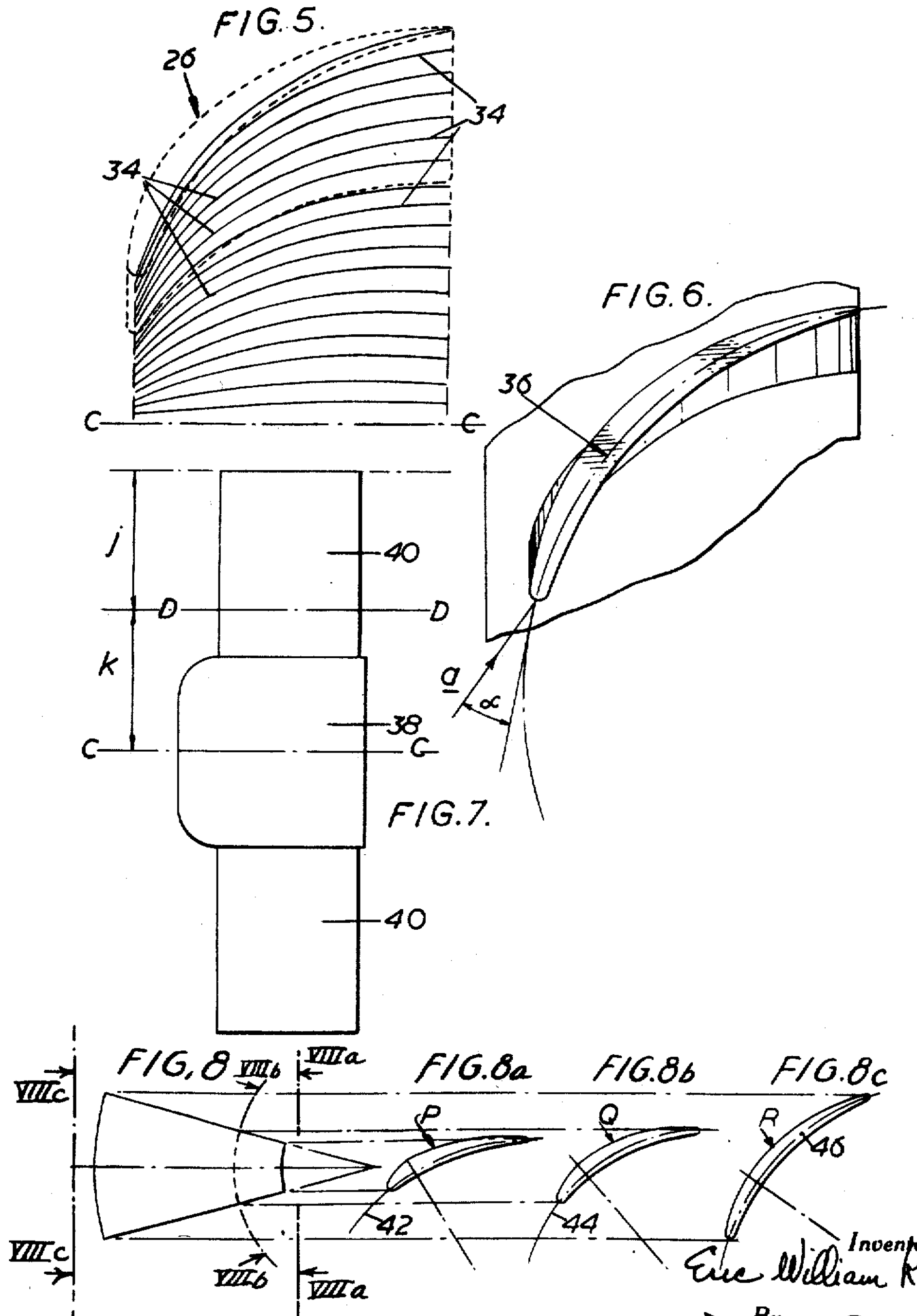

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BLADES, GUIDE VANES, AND THE LIKE FOR FANS, TURBINES AND THE LIKE

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Application July 21, 1955, Serial No. 523,514

Claims priority, application Great Britain May 19, 1952

5 Claims. (Cl. 230—134)

This is a continuation-in-part application and is in part a continuation of patent application Serial No. 355,545 filed on May 18, 1953 (now abandoned).

My invention relates to rotor or stator blades for fans, rotary pumps, blowers, compressors or like apparatus, which will be referred to herein generally as rotary turbo-machines. The invention is particularly applicable to rotary turbo-machines of the axial flow type.

Vector diagrams giving the velocities of the fluid at various points in an axial flow rotary turbo-machine are generally drawn up on the assumption that all relative and absolute velocities of the fluid leaving the rotor blades are at right angles to a straight line drawn radially from the axis of rotation. In the case of blades having convex and concave flow surfaces, the direction of the fluid leaving each blade when viewed along the axis of the rotor is controlled by the concave surface of the blade, and it follows that the assumption referred to above holds good only when the concave surface of the blade is truly radial, that is to say, when lines drawn across the concave surface of the blade and extended towards the axis of the rotor pass through the axis line or very near it.

The importance of what is stated above becomes more pronounced as the tip diameters of the blades decrease. Thus, in blowers having blade tip diameters of 6″ and less, non-tangential angles of fluid discharge from the concave surfaces of the blades when viewed axially can be responsible for excessive annular pressure head losses.

An important object of the invention therefore is to eliminate or reduce as much as possible these excessive annular head losses by providing rotor or stator blades which, when fitted in a rotary turbo-machine, ensure that the direction of the fluid flow from the blades is tangential to radial lines extending along the blade surfaces and passing through or near the axis, and which at the same time maintain a high flow characteristic V_a/V coupled with a correspondingly high pressure rise characteristic $\Delta_p/\frac{1}{2}\rho V^2$ where

Δ_p=The pressure rise through the machine;

V_a=The axial velocity of the fluid between the rotor hub and the housing of the machine in ft./min.;

V=The mean linear speed of the rotor blades in ft./min.; and

ρ=The density of the fluid in lbs./cu. ft.

when the machine is operating at the design point, that is to say, the point of maximum efficiency.

Another object of the invention is to ensure that the axial velocity of the fluid at the discharge end of the stator blades is substantially constant in value over the entire height of each stator blade, that is to say, from its root to its tip.

A further object of the invention is to provide blades which ensure that the pressure of the fluid at the discharge end of the stator blades is substantially constant in value from the root to the tip of each blade.

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In order that the invention may be clearly understood, a number of blades, rotors and axial-flow blowers in accordance with it will now be described with reference to the accompanying drawings, in which:

Figure 1 is a side view, partly in section, of a single stage axial-flow blower in accordance with the invention;

Figure 2 is a side elevation of the rotor of the blower shown in Figure 1;

Figure 3 is an end view taken on the line III—III of Figure 2;

Figure 4 is a slightly enlarged view of one of the blades on the rotor shown in Figures 2 and 3 when looking along the axis of the rotor;

Figure 4*a* is an end view of the blade shown in Figure 4 taken on the line IV*a*—IV*a* of Figure 4;

Figures 4*b* and 4*c* are both end views taken on the line IV*b*—IV*b* of Figure 4 of the other end of the blade;

Figure 5 is a diagram showing the manner in which the shape of a blade in accordance with the invention is determined;

Figure 6 is a view of a blade showing the angle which its leading edge makes with the incoming fluid;

Figure 7 is a side view of a second form of rotor in accordance with the invention;

Figure 8 is a view of one of the blades on the rotor shown in Figure 7 when looking along the axis of the rotor;

Figure 8*a* is an end view of the blade shown in Figure 8 taken on the line VIII*a*—VIII*a* of Figure 8;

Figure 8*b* is a curved section through the blade shown in Figure 8 taken on the arcuate line VIII*b*—VIII*b* of Figure 8;

Figure 8*c* is another end view of the blade shown in Figure 8 taken on the line VIII*c*—VIII*c* of Figure 8;

Figure 9 is a view corresponding to Figure 4 of a second form of blade in accordance with the invention;

Figure 9*a* is an end view of the blade shown in Figure 9 taken on the line IX*a*—IX*a* of Figure 9;

Figures 9*b* and 9*c* are both end views taken on the line IX*b*—IX*b* of Figure 9 of the other end of the blade.

The blower shown in Figure 1 is of the axial-flow type, the fluid, for example air, entering the blower as shown by the arrows *e* and leaving it as shown by the arrows *l*. The blower comprises an outer cylindrical housing **10** and a central portion indicated generally at **12**, an annular flow passage **14** being formed between them. The central portion **12** is held in position by a plurality of radial stator blades **16** which are firmly attached by welding or casting at their ends to the central portion **12** and the housing **10**.

The central portion **12** includes a casing **18** which contains an electric motor **20** the shaft **22** of which carries a rotor hub **24**. The rotor hub is provided with twelve axially-arranged blades **26** as can be seen in Figure 3.

The shape and general construction of the blades **26** is very important and their characteristics will now be described in some detail.

Firstly, it is to be noted that the leading edge **26*a*** and trailing edge **26*b*** of each blade lie on straight lines A—A and B—B (see Figures 1 and 3) which pass through the axis of rotation C—C of the rotor hub **24**. The lines A—A and B—B are truly radial to the axis C—C, so that when the blades are viewed along that axis (as in Figure 3), the leading and trailing edges of each blade **26** appear to diverge from one another, while the leading and trailing edges appear to lie parallel to one another when the blades are viewed radially to the axis C—C (as in Figures 1 and 2).

It is also to be noted from Figure 2 that each blade has a concave flow surface **26*c*** and a convex flow surface 26*d* extending from its leading edge to its trailing edge, and that the curvature of these flow surfaces vary from the root portion 26*e* of the blade to the tip portion 26*f*. In other words, the radius of curvature of the "mean camber line" and the radius of curvature of the "geometric camber line" of each blade vary from the root to the tip of the blade. The term "mean camber line" is used herein in its normal meaning as defining a line extending across the blade from its leading edge to its trailing edge lying mid-way between the concave and convex flow surfaces of the blade. That is to say, the distances from the mean camber line to the convex flow surface and to the concave flow surface are equal at any point on the mean camber line. The term "geometric camber line" is used herein to define a camber line on which the construction of the airfoil section of the blade is based, and which also extends across the blade from its leading edge to its trailing edge. It does not, however, lie midway between the concave and convex flow surfaces, but is displaced from the concave surface so that the distance from the concave surface to the geometric camber line at the point of maximum thickness of the blade is a quarter of the maximum thickness of the blade. The geometric camber line generally follows the concave surface of the blade and meets the mean camber line at the leading and trailing edges of the blade.

Figures 4*a*, 4*b* and 4*c* show the relation between the two camber lines and the concave and convex flow surfaces of one of the blades **26**. The end view D (Fig. 4*c*) is that of the blade at its tip, and the line **28** is the mean camber line which lies midway between the concave and convex flow surfaces of the blade. As far as the present invention is concerned however, the geometric camber line is more important than the mean camber line, and the end view B in Figure 4*b*, which view is also that of the blade at its tip, shows the geometric camber line at **30**. The point of maximum thickness of the blade is shown by the line Z—Z (Fig. 4*b*), and at this point the distance x between the geometric camber line and the concave flow surface of the blade is a quarter of the distance y between the concave and convex surfaces of the blade measured along the line Z—Z. The geometric camber line **30** is an arc of a circle and has a radius R at the tip of the blade.

The end view F of the blade in Figure 4*a* is that of the blade at its root. The geometric camber line is shown at **32** and has a radius r which is smaller than the value R in the cross-section E. If now the geometric camber lines at different heights of the blade be considered together, it will be found that they form a geometrical figure which, if extended to the axis of rotation C—C, becomes straight and coincides with the said axis. This is illustrated in Figure 5 which shows a series of geometric camber lines in full lines at **34** and the outline of the blade in chain lines, the blade being that shown at G in Figure 2. As the geometrical figure formed by the camber lines **34** approaches the axis C—C it becomes less curved and at the axis C—C the figure is completely straight.

An important feature of the rotor shown in Figures 1–3 is that the blades **26** have a high negative "angle of attack" or "angle of incidence." These synonymous terms define the angle which the mean camber line makes at the leading edge of each blade with the direction of the air flow under the influence of the blade. Figure 6 is an enlarged view of the blade shown at H in Figure 2, the mean camber line at the tip of the blade being shown at **36** and the direction of entry of the air being shown by the arrow a. The angle of attack at the tip of the blade is given by the angle α which can have a negative value of up to 30°. The angle of attack decreases progressively towards the root of the blade due to the variation in curvature of the blade.

The advantage of having a high negative angle of attack is that it enables the blades to be provided with a pronounced curvature. A pronounced curvature of the blades gives rise to a high mean air deflection angle resulting in a substantial value of pressure rise characteristic without abnormal pressure head losses. A further advantage is that air whirl at the leading edges of the blades is reduced and may be eliminated altogether. This enables inlet guide vanes or anti-whirl vanes to be dispensed with.

The blades shown in Figures 1–5 are all so dimensioned that their leading and trailing edges have a length which is no greater than half the maximum distance across the hub. In other words, the distance h in Figure 1 does not exceed the distance i. As a result, the radii of the geometric lines increase progressively from the root to the tip of each blade.

Figure 7 shows a rotor comprising a hub **38** and a number of blades **40**, in which the leading and trailing edges of the blades have a length which exceeds the maximum distance across the hub diameter. In this type of rotor, the geometric camber line radius of each blade increases progressively on either side of a geometric camber line of minimum radius located at a point on the blade which is about midway between the axis of rotation C—C and the tip of the blade. This point is indicated by the line D—D in Figure 7, the distances j and k being substantially equal. Figures 8*a*, 8*b* and 8*c* show three views of one of the blades **40**, the views P, Q and R being an end view of the blade at its root, a cross-sectional view at the level of the line D—D, and a different end view at its tip respectively. The geometric camber lines are shown at **42**, **44** and **46**, and the radius of the line **44** is smaller than either of the lines **42**, **46** and, indeed, any other geometric camber line of the blade.

Figures 9, 9*a*, 9*b* and 9*c* are views corresponding to those shown in Figures 4, 4*a*, 4*b* and 4*c* but of a slightly different type of blade. The blade shown in Figures 9, 9*a*, 9*b* and 9*c* has convex and concave flow surfaces which are true arcs of a circle at all levels of the blade between its root and tip. End views S and T (Figs. 9*c* and 9*b*) are those of the blade at its tip while the end view U is that of the blade at its root. The mean camber line is shown at **48** (Fig. 9*c*) in end view S and the geometric camber lines are shown at **50** and **52** (Figs. 9*b* and 9*a*) in the other two end views. A blade of this type is particularly suitable for blowers having an air speed Mach. Number greater than 0.3.

The rotor shown in Figures 1–3 is designed for Mach. Numbers up to about 0.3 and for this reason the leading edge of each blade appears to coincide with the trailing edge of the blade next to it when the rotor is viewed along the axis C—C (as in Figure 3). Rotors for use in blowers operating at Mach. Numbers higher than 0.3 will not necessarily have blades with axially-aligned leading and trailing edges, but the blades will, of course, have the special characteristics set out above.

I claim:

1. For use in a rotary-turbo machine having an axis of rotation for the rotatable parts thereof; said rotatable parts including a rotor comprising a central hub, a plurality of radially extending blades peripherally spaced about said hub and having their inner ends extending from said hub, said blades being of airfoil sections and each of said airfoil sections comprising a concave forward face and a convex rear face, said blades being twisted along their spans from the outer to the inner ends, the twist progressively decreasing from the outer to the inner ends of the blades, and the blade sections having an arcuate geometric camber line located between the concave and convex faces and extending from the leading to the trailing edge of the blade and approximately one-quarter the thickness of said sections from the concave face of the blade, the surface defined by an infinite number of said arcuate geometric camber lines defining a surface which if extended to the axis of the rotor would be in a line that coincides with the axis thereof; said leading and trailing edges of the blades lying in straight radial lines when viewed in a direction along the axis of the rotor.

2. In a rotary-turbo machine, as set forth in claim 1, said leading and trailing edges each having a length which is no greater than half the maximum distance across the hub; and the diameters of the geometric camber lines increasing progressively from said root portion to the tip portion of each of said blades.

3. In a rotary-turbo machine as set forth in claim 1, said leading and trailing edge having a length which exceeds half the maximum distance across the hub, and the radii of said geometric camber lines increasing progressively on either side of a geometric camber line of minimum radius located between said root portion and said tip portion of each of said blades.

4. In a rotary-turbo machine as set forth in claim 3, said geometric camber line of minimum radius being located at a point in each of said blades midway between said axis of rotation on said tip portion of each of said blades.

5. In a rotary-turbo machine as set forth in claim 1, said blades having a negative angle of attack of up to 30° at said tip portions, said angle of attack decreasing progressively towards said root portions.

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