May 20, 1952 E. J. McBRIDE 2,597,510

BLADE ELEMENT FOR ROTARY FLUID MACHINES

Filed April 15, 1947 2 SHEETS—SHEET 1

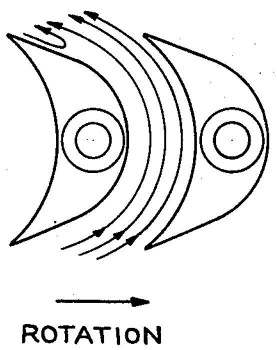


FIG. 1

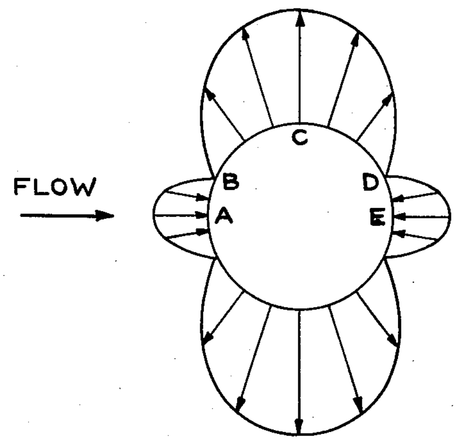
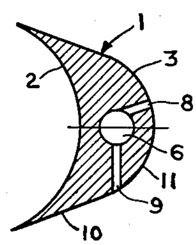


FIG. 2

FIG. 3



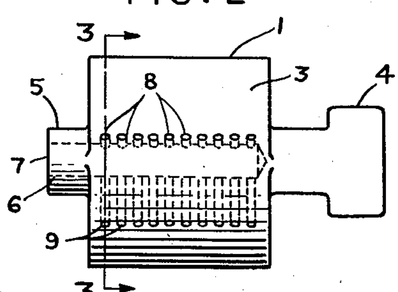


FIG. 4

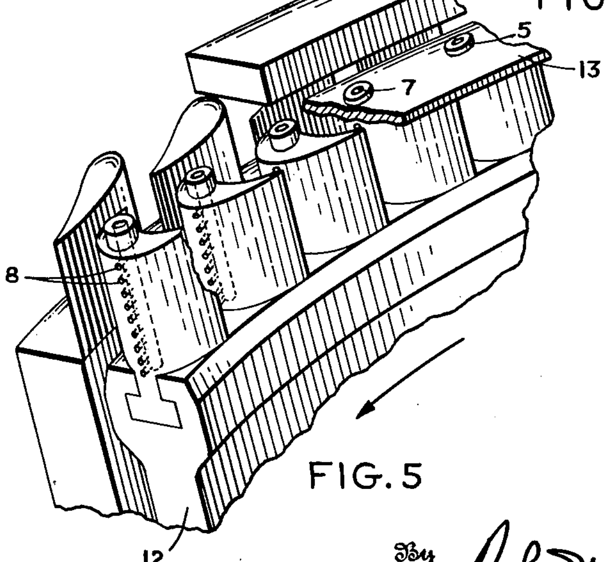


FIG. 5

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BLADE ELEMENT FOR ROTARY FLUID MACHINES

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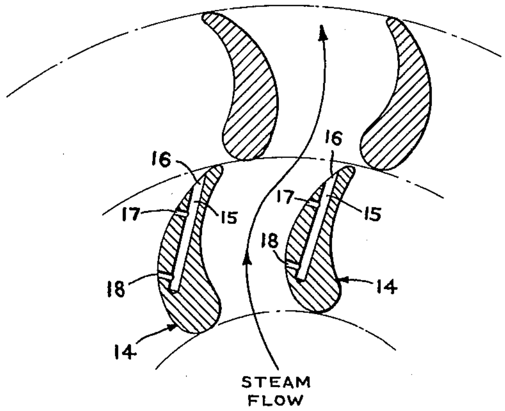

FIG. 6

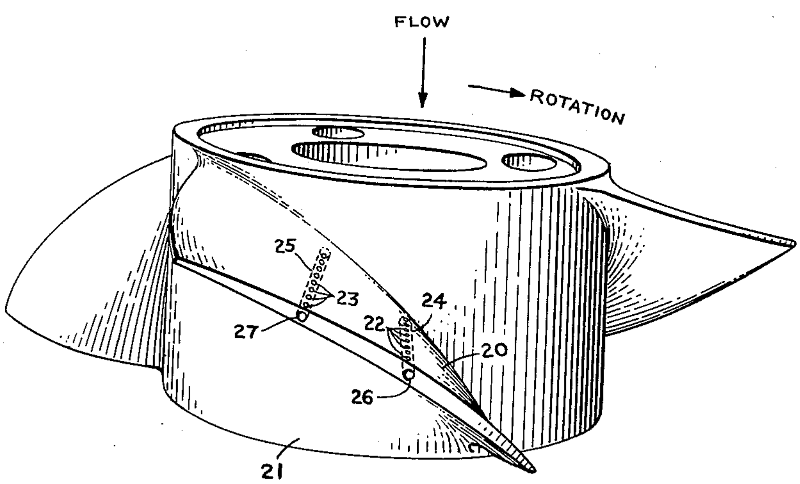

FIG. 7

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BLADE ELEMENT FOR ROTARY FLUID MACHINES

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6 Claims. (Cl. 230—134)

1

This invention relates to rotary fluid machines of the type exemplified by turbines, blowers, pumps, compressors, superchargers, etc., and, in particular, concerns the fluid engaging blades or buckets of the rotors thereof.

The primary object of this invention is to increase the efficiency of rotary fluid machines by reducing the energy loss in the passage of fluid between the moving blades.

With this and other objects in view, as may appear from the accompanying specification, the invention consists of various features of construction and combination of parts, which will be first described in connection with the accompanying drawings, showing a blade element for rotary fluid machines of a preferred form embodying the invention, and the features forming the invention will be specifically pointed out in the claims.

In the drawings:

Figure 1 is a schematic diagram showing back flow occurring on the discharge side of the convex surface of the passage between the turbine blades of an impulse turbine.

Figure 2 is a schematic diagram showing the theoretical pressure distribution on a long cylinder subject to the flow of a perfect, incompressible fluid.

Figure 3 is a cross section of the improved turbine blade taken along the line 3—3 of Figure 4.

Figure 4 is a side view of the turbine blade.

Figure 5 is a view in perspective of a portion of one stage of an axial turbine and shows the blades assembled to the turbine wheel and shroud ring.

Figure 6 is a schematic view showing the invention applied to the buckets of an outward radial flow turbine.

Figure 7 is a perspective view of a portion of an axial flow impeller having a vane embodying the invention.

Steam or gas flowing through the passage formed by the two moving buckets of Figure 1 encounters two types of bucket resistance arising because of the fact that steam is to some extent viscous: (1) a skin friction resistance which is minimized by making the blade surface as smooth as possible, and (2) an eddy-making resistance. The present invention reduces the eddy-making resistance of the buckets.

Figure 2 shows the theoretical pressure distribution on a section of a long cylindrical body due to the transverse flow of a non-viscous, incompressible fluid. In the regions AB and DE there is a positive pressure on the cylinder while in the region BD there is a negative pressure on the cylinder. A particle flowing near the surface of the cylinder will undergo changes in its velocity as it moves from A to E but in the flow of perfect fluids these changes are exactly balanced by changes in pressure so that the total energy of the particle at E is the same as it was at A. In the flow of viscous fluids, however, kinetic energy is lost as the particle flows from A to E and the particle will not have a sufficient increase in velocity during its flow over the region of decreasing pressure from A to C to enable it to continue its travel against the increasing pressure in the region CE. At a point in CE when its kinetic energy is spent, the pressure will force it to flow back toward A to interfere with other particles flowing toward E. In the resulting disturbance the boundary layer is separated from the surface of the cylinder and a wake or eddies are formed which represent a distinct loss in the energy of the fluid and the intermittent formation of which may set up vibrations in the associated structure.

2

If it be assumed that the above analysis represents in a general way the basic mechanism causing separation in the flow of fluid over the surface of a blade, it follows that the separation may be controlled by changing the pressure distribution on the surface of the blade. Since the pressure distribution is determined by the shape of the body, the usual method of overcoming the eddy-making resistance in turbines, or other rotary fluid machines of the type mentioned above, is by streamlining the buckets or blades. However, the provision of sufficient blade thickness for mechanical strength limits the degree of streamlining which can be secured and the tendency toward eddy formation can seldom be completely eliminated so that other methods of preventing separation are useful. In such cases the present invention may be employed.

In terms of Figure 2, the principle of the present invention is to lower the pressure in the region CE by connecting the surface of the body in that region to a second region of lower pressure and thereby to draw off the boundary layer and reduce or eliminate the back flow which causes separation and the formation of eddies. The present invention also contemplates a novel means for creating said second region of lower pressure, the novel means including a chamber within the blade which communicates with the affected surface regions and which is disposed so that the fluid therein is evacuated under the influence of centrifugal force due to the rotation of the rotor carrying the blade.

Figures 3, 4, and 5 show an impulse turbine blade embodying the principle of this invention. The blade 1 has a bucket formed by the usual concave face 2 and approximately parabolic rear surface 3 and a dovetailed end portion 4 for attaching the blade to the turbine wheel 12. The end of the blade opposite to the dovetail 4 has a short cylindrical extension 5 which fits into holes in the shroud ring 13 whereby it may be riveted to the shroud ring. The blade has a blind, longitudinal hole which is drilled in the extension 5 and the blade body and terminates near the lower end of the bucket surface to form the chamber 6. The opening in the extension 5 is the outlet 7 for the chamber 6. A plurality of small holes or bleed-off passages are drilled adjacent a line of tangency hereinafter described between the inlet tangent plane 10 and the convex portion 11 of the approximately parabolic surface 3, to connect it with the chamber 6 and permit limited quantities of fluid flowing over the surface 3 to be bled off through the outlet 7. The holes 8 and 9 could, of course, be thin slots or any other means which will perform the function of connecting the surface 3 to the chamber 6. It is also clear that more than one chamber 6 could be provided to communicate with the sets of holes 8 and 9.

The line of tangency between the inlet tangent plane 10 and the convex portion 11 of the approximately parabolic plane 3 will determine the position of holes 8 and 9. Accordingly, holes 8 and 9 do not have to be spaced in straight lines as indicated in Figures 4 and 5, but they may be spaced at random in accordance with trial and error procedures or theoretical considerations as set forth above which must be utilized to determine the line of tangency. It has been learned, however, that because of critical factors which cannot be properly considered in the theoretical analysis, most successful results are obtained when the hole pattern is based on the above set-out theoretical considerations in conjunction with experimental studies employing the usual methods for determining the regions of flow separation. Once the line of tangency is determined, holes 9 may be drilled whereby their most forward edges will lie on the line and the openings thereof lying just behind the line or in the actual area where separation is occurring, so that the boundary layer is removed in that the pressure is reduced and separation prevented in accordance with the theory heretofore indicated.

While applicant has demonstrated the use of an approximately parabolic outer surface, composed of an inlet plane surface tangent to a convex intermediate surface, and an exit plane surface tangent to the convex intermediate surface, in the preferred form of the invention, it is believed obvious that the outer surface of the turbine blade could be developed from several basic shapes, including a true parabolic surface, and that the same results would be obtained. The line of tangency would then be determined empirically by the separation point of the inlet fluid from these surfaces and holes 8 and 9 would then be drilled as above described.

Fluid within the chamber 6 is subjected to centrifugal force since the chamber 6 is substantially radial of the axis of rotation of the machine's rotor, or, in this case, the turbine wheel 12. The fluid, therefore, flows outward through the outlet 7 into the casing (not shown). The net effect is to lower the surface pressure locally about the holes 8 and 9 so that the boundary layer will be forced through the holes, into the chamber, and thence into the casing. Thus, the back flow and consequent eddy-making resistance will be reduced or eliminated.

In Figure 6 the invention is applied to the rotating buckets 14 of an outward radial flow turbine. The chamber 15 is cross-wise of the blade; that is, it extends from the inlet side toward the outlet edge in contrast to the corresponding chamber 6, previously discussed, which was longitudinal of the blade used in the axial flow machine. However, the chamber 15 is functionally similar to chamber 6 since it is arranged so as to be substantially radial with respect to the axis of rotation of the rotor (not shown) and fluid therein will be forced outward due to centrifugal action. The outlet 16 of the chamber 15 may be in the discharge end of either the convex or concave blade surface, being shown in Figure 6 in the convex surface. Holes such as 17 and 18 connect the convex surface of the blade 14 to the chamber 15 so that the boundary layer will be removed in accordance with the mechanism already explained.

Figure 7 shows the invention embodied in the vane 20 of an axial flow impeller 21. In this case the set of holes 22 and the set of holes 23 in the convex vane surface are spaced too far apart to be connected to the same central chamber, i. e., one such as chamber 6 or 15 in the illustrated preferred forms of the preceding embodiments. Two chambers 24 and 25 are therefore provided that communicate with the holes 22 and the holes 23, respectively. These chambers have outlets 26 and 27 in the outer peripheral edge of the vane 20 and are substantially radial of the axis of rotation of the impeller 21. Consequently, the boundary layer on the convex surface of the vane will be drawn through the holes 22 and 23 and thrown radially outward in the chambers 24 and 25 by centrifugal force to be discharged at the outer peripheral edge of the vane through the outlets 26 and 27.

Those skilled in the art will understand that the invention is not confined to the specific structures described and illustrated and that it may be modified so as to be applied to other fluid engaging elements within the limitations of the claims.

What is claimed is:

1. In a compressible fluid turbine, a rotary member, a plurality of blades mounted thereon in circumferential alignment and having radially disposed axis, said blades having concave and approximately parabolic surfaces, means defining curved flow passages for fluid actuating said rotary member, said means including, a convex surface in the medial portion of said approximately parabolic surface, and an inlet plane surface on said parabolic surface tangent to said convex surface, said blades having a plurality of bleed-off openings on said convex surface adjacent the point of tangency of said inlet plane surface to connect said convex surface to a region exterior of said flow passages.

2. In a compressible fluid turbine, a rotary member, a plurality of blades mounted thereon in circumferential alignment and having radially disposed axis, said blades having concave and approximately parabolic surfaces, means defining curved flow passages for fluid actuating said rotary member, said means including, a convex surface in the medial portion of said approxi-

mately parabolic surface, and an inlet plane surface on said approximately parabolic surface tangent to said convex surface, chamber means disposed in the radial line of said blades and opening on said convex surface adjacent the point of tangency of said inlet plane surface, said chamber means being so constructed and arranged that centrifugal force acting therethrough when the rotary member is rotated will tend to lower the pressure on said convex surface past the point of tangency.

3. A blade for axial flow turbines comprising a concave fluid guiding surface and an approximately parabolic fluid guiding surface, said approximately parabolic surface including, a convex surface in the medial part thereof, and tangent thereto an inlet plane surface, said surface rendering the blade substantially crescent-shaped in a cross-section normal to the axis thereof, means at one end of said blade for attaching said blade to a turbine wheel, a longitudinal chamber extending from the other end of said blade for a substantial portion of its length, and a plurality of spaced holes on the convex surface of said blade adjacent the point of tangency of said inlet plane surface communicating with said longitudinal chamber to lower the pressure on said convex surface during operation of said turbine.

4. In a blade disposed radially on the rotor of a fluid operated rotary machine, a concave fluid guiding surface and an approximately parabolic fluid guiding surface, said approximately parabolic surface including, a convex portion in the medial part thereof and tangent thereto an inlet plane surface, means for utilizing centrifugal action due to rotation of the blade to substantially remove the boundary layer on said convex portion of the approximately parabolic surface of the blade comprising, at least one chamber in the axial line of said blade, said chamber having an outlet at its outer radial end, inlet means for said chamber formed by a plurality of fluid passages opening on said convex portion adjacent the line of tangency of said inlet plane surface, said chamber being so constructed and arranged that centrifugal force acting therein when the rotary machine is in operation will urge it to evacuate causing the pressure on said convex surface to be reduced and thus drawing off the boundary layer thereon to reduce the eddy-making resistance of said convex portion.

5. In a blade disposed radially on the rotor of a fluid operated rotary machine, a concave fluid guiding surface and a parabolic fluid guiding surface, said parabolic surface including, a convex portion in the medial part thereof and tangent thereto an inlet plane surface, means for utilizing centrifugal action due to rotation of the blade to substantially remove the boundary layer on said convex portion of the parabolic surface of the blade comprising, at least one chamber in the axial line of said blade, said chamber having an outlet at its outer radial end, inlet means for said chamber formed by a first plurality of fluid passages opening on said convex portion adjacent the line of tangency of said inlet plane surface, a second plurality of fluid passages forming inlet means for said chamber opening on said convex portion of the parabolic surface of said blade at a point advanced of said line of tangency, said chamber being so constructed and arranged that centrifugal force acting therein when the rotary machine is in operation will urge it to evacuate causing the pressure on said convex surface to be reduced and thus drawing off the boundary layer thereon to reduce the eddy-making resistance of said convex portion.

6. In a blade disposed radially on the rotor of a fluid operated rotary machine as claimed in claim 5 wherein said second plurality of fluid passages forming inlet means for said chamber is disposed at an obtuse angle to the first plurality of fluid passages.

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