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BLADING STRUCTURE FOR AXIAL FLOW TURBO-MACHINES

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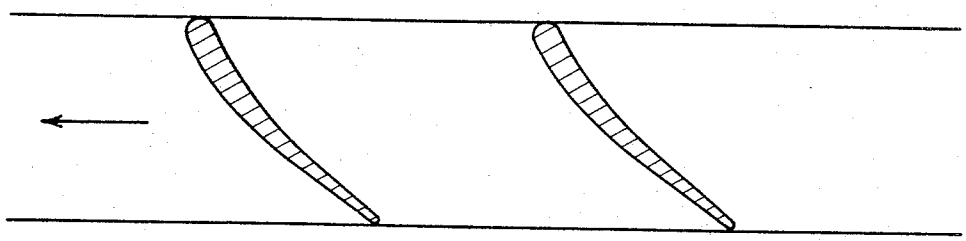


Fig. 1

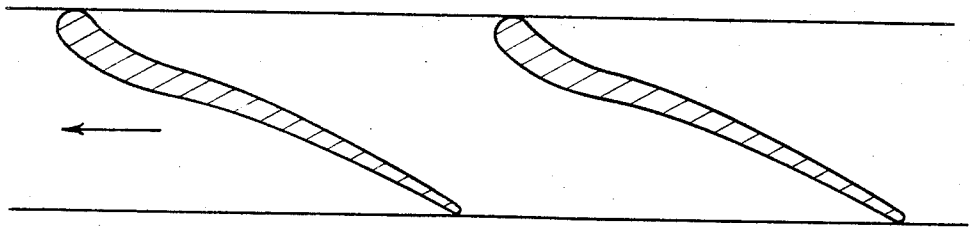


Fig. 2

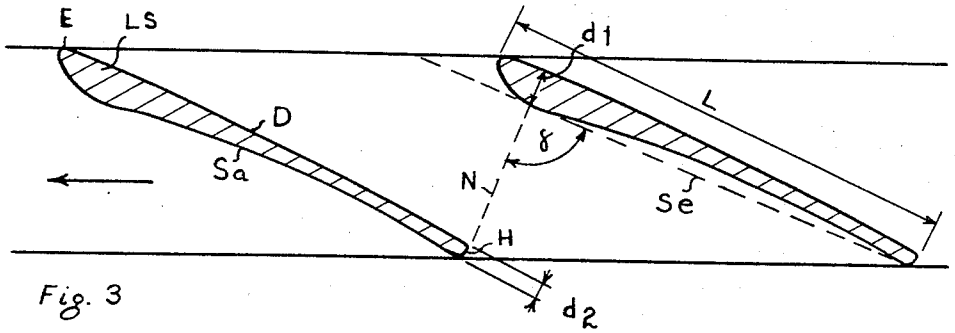


Fig. 3

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BLADING STRUCTURE FOR AXIAL FLOW TURBO-MACHINES

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The present invention relates to an improvement in the blading structure for the rotor elements of thermal axial-flow turbo-machines having great circumferential speed, particularly for the last stage of condensation steam turbines where at least the radially outer tip portions of the blading lie in a zone of transsonic flow.

The construction of condensation steam turbines of large output requires low pressure parts with exit surfaces as large as possible, owing to which especially the rotor blading for the last stage is required to be very long. These very long blades must not be too close together, so as to assure their fixation in the rotor with sufficient certainty, and further a sufficiently wide flow channel must be provided near the root portion of the blading. Also, in the case of very long blading, there is the additional factor of great flaring whereby the distance between the tips of adjacent blades becomes considerable.

In the largest turbines constructed, circumferential speeds of 600 meters/sec. and more are reached at the tips of the rotor blades, the sonic speed of the steam being about 370 meters/sec. In the radially outer portion of the blading, the relative flow is trans-sonic, i.e. the steam enters the blading with sub-sonic speed and leaves it with super-sonic speed, which latter may be a Mach number of the order of 1.7, or even higher.

So long as the flow velocity in the blading is only just above Mach 1, a conventional airfoil wing profile for the blading suffices. With increasing unit power of the turbo sets and increasing circumferential and steam speeds, the increasingly thinner airfoil profiles are no longer adequate. The gradient processed in the last stage decreased, the desired high Mach number at the exit was not reached, and the stage efficiency decreased due to jet deflection at the blade exit. It could also happen, as subsequent tests verified, that the entire stage practically no longer furnished any power.

An improvement over the airfoil blade contour was obtained by use of a so-called S blade, which permitted a higher Mach number to be reached. At other equal dimensions and equal number of blades, although there resulted the same distance at the tips of the blades, jet conduction was better than the airfoil configured blade because of the more favorable profile. At higher Mach numbers, there occur also with the S type of blade configuration relatively strong jet deflections and shock losses, and also the almost identical shape of the suction and compression sides of the thin blade profiles leads to a poor efficiency.

The object of the present invention is to provide an improved profile for the rotor blading of thermal, axial flow turbo-machines for operation at high rotor speeds which avoid the disadvantages of prior blade profiling and yet present good efficiency even at the initially mentioned high Mach numbers. The improved blade profile and spacing between adjacent blading in the blade row is shown in the accompanying drawings in comparison with prior known blade profiling. In these drawings:

FIG. 1 illustrates one known prior art rotor blading profile, two of the blades in a blading row being illustrated, and being of the aforementioned airfoil contour;

FIG. 2 is a view similar to FIG. 1 but showing another prior art blade profile wherein the blades have a generally S shape; and

FIG. 3 is a view similar to FIGS. 1 and 2 but showing the improved blade profile in accordance with the present invention.

With reference to the drawings, FIGS. 1 and 2 show, respectively, the airfoil and S shape blading profiles and the disadvantages of these have already been explained. In contrast with these two prior known blade profiles is the present improved profile. This new profile is characterized in that each blade begins at its root portion with a profile of known configuration and changes over towards its tip portion into a profile in which:

(1) The pressure side of the blade is straight, or only slightly convex.

(2) The suction side of the blade is concave, but with a smaller radius of curvature than the compression side.

(3) The profile toward the inlet edge of the blade is barrel-shaped, or club-shaped.

(4) The greatest profile thickness occurs in the forward quarter of the chord length rearwardly of the inlet edge.

(5) The profile thickness at the blunt, rear edge is from about 2 to 4 percent of the chord length; and

(6) The blades in the blading row are arranged at such a distance from one another at their tips that a normal from the rear edge of one blade to the profile chord of an adjacent blade meets the latter at substantially the point where the blade has its greatest thickness.

The first two of these features, convex curvature on the compression side and concave curvature on the suction side can be realized with a thin profile only with difficulty, or not at all. However, by establishing a heavy i.e. thick profile portion toward the inlet edge of the blade, and a considerably thickened rear edge, the task is accomplished. The radially inner portion of the blade may then present any desired, appropriate profile of known form which changes over into the new profile form in the radially outer portion of the blade.

The relationships described are evident from FIG. 3 of the drawing which shows a development of a cylindrical surface concentric with the rotor axis, and intersecting the blades in the vicinity of the blade tips. The pressure side of the blade LS is indicated at D and S*a* is the suction side. The chord length is indicated by L and E designates the inlet edge of the blade. The rear edge of the blade is indicated at H, and its thickness at such point by *d*2. The greatest profile thickness is designated by *d*1, and S*e* indicates the profile chord of the blade. N is the normal to the profile chord S*e* of the next adjacent blade, which it therefore meets at an angle of 90°. This normal strikes the adjacent blade at its point of greatest thickness.

By means of the improved blade profile configuration in the vicinity of the tips of the blades, the efficiency, especially at the radially outer portion of the rotor blades, and hence the efficiency of the entire stage is greatly increased. In addition to the foregoing advantages which have been explained, other advantages are, that blade flutter, especially at the outlet portion, occurring in the case of flat blades with thin rear edges, is largely avoided. The relatively thick, only slightly rounded rear edge, which causes no additional flow losses, facilitates the manufacturing process, so that the waste factor in blade production is reduced. The wide, heavy inlet edge of the blade is more suitable for application of a protection against erosion than would be a thin inlet edge.

Moreover, the improved rotor blade profile, as explained above is applicable to all thermal, axial flow type turbo machines.

I claim:

1. Rotor blading for the rotor element of a thermal, axial flow turbo machine operating at high speeds such

as to establish a zone of transsonic flow at least in the radially outer portions of the blades and which have a profile in said radially outer portions wherein the pressure side of the blade is straight or slightly convex, the suction side is concave and with a radius of curvature smaller than that on the pressure side of the blade, the forward portion of the blade terminating in the inlet edge is barrel-shaped or club-shaped, the maximum thickness of the blade occurs in the forward quarter of the chord length rearwardly of the inlet edge, the thickness of the blade at its rear blunt edge is from 2 to 4 percent of the

chord length, and the tips of adjacent blades are spaced apart such that a normal from the rear edge of one blade to the profile chord of an adjacent blade meets the latter at substantially its point of maximum thickness.

2. Rotor blading as defined in claim 1 and which constitutes the last stage of a condensation steam turbine.

No references cited.

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