March 4, 1930. J. DE FREUDENREICH ET AL 1,749,528

BLADING FOR REACTION TURBINES

Filed May 13, 1926

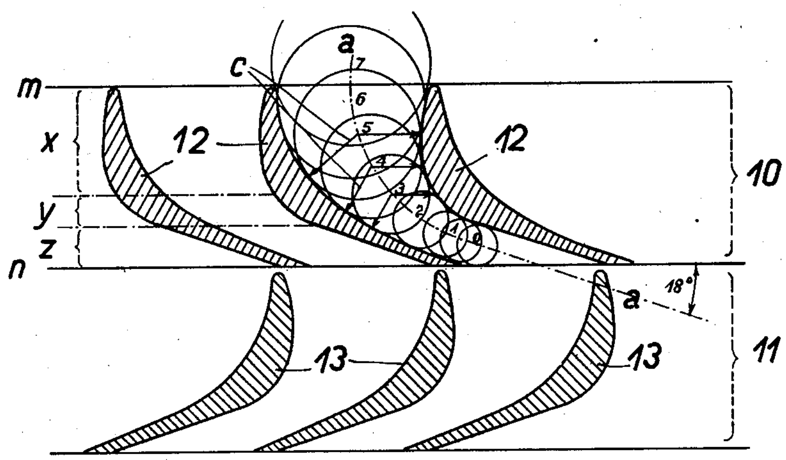

Fig.1.

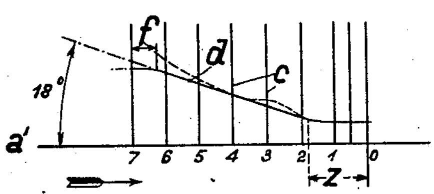

Fig.2.

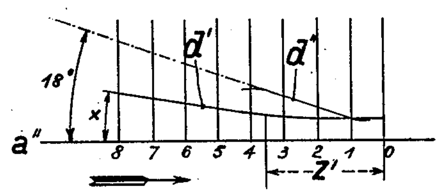

Fig.5.

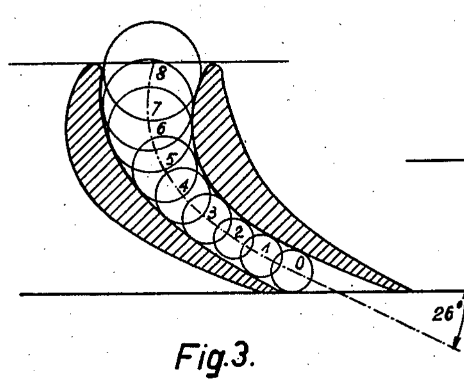

Fig.3.

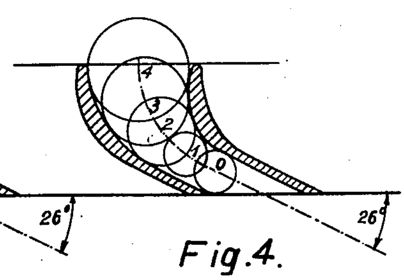

Fig.4.

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UNITED STATES PATENT OFFICE

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BLADING FOR REACTION TURBINES

Application filed May 13, 1926, Serial No. 108,728, and in Switzerland May 27, 1925.

This invention relates to the construction of turbines actuated by expansion fluid, as exemplified by steam turbines. It pertains particularly to steam turbines of the reaction type, and has to do with the construction or arrangement of the blading for both or either the stator or rotor.

The general object of the invention is the provision of a blading arrangement for reaction turbines which will increase the power efficiency of the engine.

Another object is the provision of a blading arrangement which will, in many instances, permit a reduction in the size of the machines.

Another object is the provision of a construction which will reduce cost, by decreasing the number of blades in a stage.

Other and further objects will be pointed out or indicated hereinafter, or will be obvious to one skilled in the art upon an understanding of the invention.

In the drawing forming a part of this specification we illustrate two designs embodying the present improvements, but the same are presented for the purpose of illustration only, and are not to be construed to impose limitations on the claims short of the true and most comprehensive scope of the invention in the art.

In the drawing,

Fig. 1 is a diagrammatic illustration of a portion of a stage of blading demonstrative of the invention, showing three blades each of adjacent stator and rotor rings, the blades being shown in section taken concentrically with the turbine axis.

Fig. 2 is a graph illustrating the relationship of parts of the blade profile.

Fig. 3 is a section diagram of blading of the conventional Parsons design.

Fig. 4 is a diagram of a blading profile demonstrative of the invention in a design differing from that of Fig. 1.

Fig. 5 is a graph illustrating the relationship of certain parts of the respective structures illustrated in Figs. 3 and 4.

Heretofore in the designing of reaction turbines, so far as we have been able to ascertain, rapid changes in the cross section and direction of the flow of steam through the blading have been regarded as disadvantageous, and consequently have been avoided, the designs having been arranged to give the steam passages or channels between the blades a form of gradually contracting contour free from abrupt change of direction. Moreover, it has been considered of importance to have the narrower portion of the passage at the exit side comparatively long in relation to the entrance portion.

By a course of studied experimental tests, made for the purpose of demonstrating the present invention, we have ascertained that substantially increased efficiencies may be secured by a construction differing radically in certain particulars of the blade profile and spacing from the designs heretofore considered most effective and as a result more or less standardized. Our tests in connection with the development of the present blade profile have shown, contrary to the beliefs heretofore held, that the design and arrangement of blading which provides a steam passage which is comparatively wide in the portion adjacent the entrance side, and changes direction quite sharply, giving an acute exit angle and having the narrow exit portion of the path comparatively short, gives substantially increased power efficiency, as well as various constructional advantages.

The nature of the invention may be ascertained by reference to the drawing, wherein Fig. 1 illustrates a profile and arrangement of our improved blading, as applied to an axial-flow steam turbine. In this figure the upper row of blades, designated 10, represents a section of blading on a wheel or rotor of a reaction turbine, while the row designated 11 represents a section of a portion of the adjacent row of fixed blading. It is well to observe at this point that our new blading construction is equally adapted for both moving and stationary stages of reaction turbines, and that it can be employed to best advantage when utilized in both in conjunction. The moving blades are designated 12 and the secondary blades 13. It will be observed that their form and arrangement are such that the steam passage or channel between the blades is quite wide at the entrance side, in comparison to the entire extent of the passage in the axial direction. It will be observed furthermore, that the channel continues as relatively wide from the entrance opening throughout somewhat more than one half of its total extent, on the axial line of the machine (perpendicular to lines *m* and *n*) finally contracting abruptly to a much narrower form at the exit side. This contracted exit portion of the passage, which we will designate the velocity portion, is comparatively short in respect to both the total length of the passage and the exit portion of the previous standard design, which is illustrated in Fig. 3. Thus the passage may be roughly apportioned as a pressure portion, which is relatively wide, an exit portion which is narrow and quite short, and an intermediate contracting portion in which the direction of flow changes rapidly. In the illustrated example the pressure portion may be regarded as the zone X, the intermediate portion as the zone Y and the velocity portion as the zone Z. As a result of these particulars of the design, the change in direction of the flow passage is relatively abrupt as compared with the previous design, resulting in the turning of the steam path to an acute exit angle in considerably shorter length. In the illustration given, the exit angle is approximately 18°, which is suggested as representing an average between the limits of the most effective arrangements, exit angles varying between 16° and 20° having been found productive of the best effects. We have ascertained also that the rate of contraction in the width of the steam passage from the pressure portion to the velocity portion may be determined and laid out in accordance with a fairly accurate rule, of which the following method is an illustration.

Let the line *a'* in Fig. 2 represent the development of the median steam path *a—a* between the blades, and the cross sections 0, 1, 2, 3 . . . 7, set up on the line *a'* represent the radii of the correspondingly numbered circles inscribed in the steam passage tangent to the blade profiles, as shown in Fig. 1. With a properly chosen profile the line *d* generated along the ends of the radii *c* should incline toward the line *a'* at an angle of something over 15° throughout that portion representative of the intermediate zone Y. The end portions of the line *d* will deviate from the intermediate portion, the part Z representing the comparatively straight restricted velocity portion of the steam passage, while the part *f* represents the portions where the blades are rounded off at entry in the example shown. It will be observed in the example given that the portion Z represents only between one fourth to one fifth of the length of the entire path *a—a*. An effective design may also generate a line corresponding to the line *d* but curved, the chord of the intermediate portion being inclined at an angle of more than 15° to the line *a'*. In order that the condition for a rapid change of the passage width may be fulfilled, said curved line in the intermediate portion should be convex upwardly. If concave, it is a sign that the transition will be gradual. The dotted curved in Fig. 2 is illustrative of one form.

The novelty of this type of blade profile, and the manner in which it differs from the usual standard reaction blading (Parsons), may be demonstrated by a comparison with a similar analysis of the steam passage of the latter. In Fig. 3 is shown a diagram of standard Parsons blading, and in Fig. 5 a diagrammatic analysis of the same obtained by the method described above. It will be observed that in this diagram the line *d'*, corresponding to the line *d* of Fig. 2, is concave upwardly in the intermediate portion and makes an angle of less than 15° to the line *a''*. The narrowest section Z' comprises a considerably greater proportion of the line *d'*, demonstrating that the length of the contracted exit portion of the steam channel is considerably greater than is the case with profiles arranged according to the present invention.

While one advantage accruing from the present invention lies in the fact that it allows of a very small exit angle and a corresponding increase in the peripheral component of the steam force on the moving blades, with reduced frictional losses, improved power factor efficiencies may be obtained by use of the invention in suitably designed blading in which the exit angle is greater than 20°. In Fig. 4 is shown an example of such an arrangement, the profile being shaped in accordance with the method described above, and illustrated by the line *d''* in Fig. 5. As demonstrated by the analysis, this design presents a profile from which the line *d''* is generated to extend through the greater proportion of its length at an angle of more than 15° to the line *a''*.

In the operation of the turbine, it is believed, the steam entering a ring of rotary blading exerts a momentary initial impulse on the blades, following which the remaining kinetic energy of the steam becomes converted into pressure which builds up in the pressure portion of the passage. The pressure, in turn, is transformed into kinetic energy again in the velocity portion, exerting its reaction against the blades. The heat drop incident to the development of the exit velocity is very rapid, so that the reaction effect is very pronounced, and the friction losses low, even with a small exit angle.

While one of the great advantages of the invention as demonstrated by practical use, is the increased power efficiency obtained, which in various instances has been found to be as high as 6%, other important and useful results follow from the employment of the principles cha. ·cterizing the invention. For example, it wi: be observed that with the same circumferential pitch of the new blading as employed in the old, the width of the blades may be materially reduced. Likewise, the width of the stages may be substantially reduced. Furthermore, there may also be a reduction in the number of blades required on a given diameter. These various factors result in an important decrease in the cost of manufacture, and it is believed, contribute somewhat to the strength and stability of the mounting of the blades. As an example of a further development of the construction disclosed, reference is made to our copending application Serial No. 206,491, filed July 18, 1927.

What we claim is:—

1. Reaction turbine blading comprising blades extending radially and defining intervening steam passages, the blades having a profile and arrangement giving said passages a relatively wide pressure portion at the entrance side and a relatively short and restricted velocity portion at the exit side, said portions connecting through an intermediate portion of rapidly contracting width wherein the blade profile converges on the mean steam path of the passage at a rate exceeding that of the sides of an angle of 15°.

2. Reaction turbine blading as specified in claim 1, wherein the intermediate portion of the steam passage changes the direction of steam flow rapidly.

3. Reaction turbine blading as specified in claim 1, wherein the pressure portion of the steam passage is longer, on the axial line of the turbine, than is the velocity portion.

4. Reaction turbine blading as specified in claim 1, wherein the length of the velocity portion is not over one fourth of the length of the total median steam path.

5. Reaction turbine blading as specified in claim 1, wherein the exit angle is less than 20°.

6. In a reaction turbine, the combination with a rotary member, of reaction blades mounted thereon in alignment circumferentially, said blades spaced to provide intervening steam passages, the blade profile defining said passages with a relatively wide pressure portion on the inlet side and a relatively narrow and short velocity portion on the exit side, said passage changing direction abruptly from the pressure portion to the velocity portion and its median line progressing throughout its length from inlet to outlet in the direction counter to that of the blades' movement.

7. Reaction turbine blading comprising blades extending radially and defining intervening steam passages, the blades having a profile and arrangement such that the envelope of a series of circles inscribed in the passage, when they are set up on a straight line of centers, converges for the greater part of its length on said line of centers at an angle in excess of 15°.

8. In a fluid turbine, complementary blades spaced with respect to each other to provide a fluid passage; the profile of adjacent faces of said blades being such as to provide said passage at the entrance side thereof with a relatively wide pressure portion, to provide said passage at the exit side thereof with a contracted velocity portion relatively short as compared with the length of said passage, and to provide said passage intermediate said portions with a contracting portion angularly disposed at all points with respect to said pressure portion in a direction counter to that of the blade movement to provide at such intermediate contracting portion for relatively rapid change in the direction of flow of the fluid.

9. Blading for reaction turbines, comprising identical radial blades arranged to afford a curved intervening steam passage having a wide entry side in which the mean steam path curves continuously rearwardly, the sides of said steam passage contracting first slowly and then rapidly toward each other, and the portion of said steam passage between the contracting portion and the exit being shorter than the rapidly contracting portion.

10. Blading for reaction turbines, comprising identical radial blades arranged in circular rows to afford curved intervening steam passages, each passage having a wide pressure portion at the entry side, a short velocity portion at the exit side and a rapidly contracting accelerating portion between the pressure and velocity portions, the mean steam path in the pressure and accelerating portions bending continuously toward the exit side in the circumferential direction of the row.

In testimony whereof we have hereunto subscribed our names at Zurich, Switzerland, on the 27th day of March, A. D. 1926.

JEAN DE FREUDENREICH.
KARL FREY.