

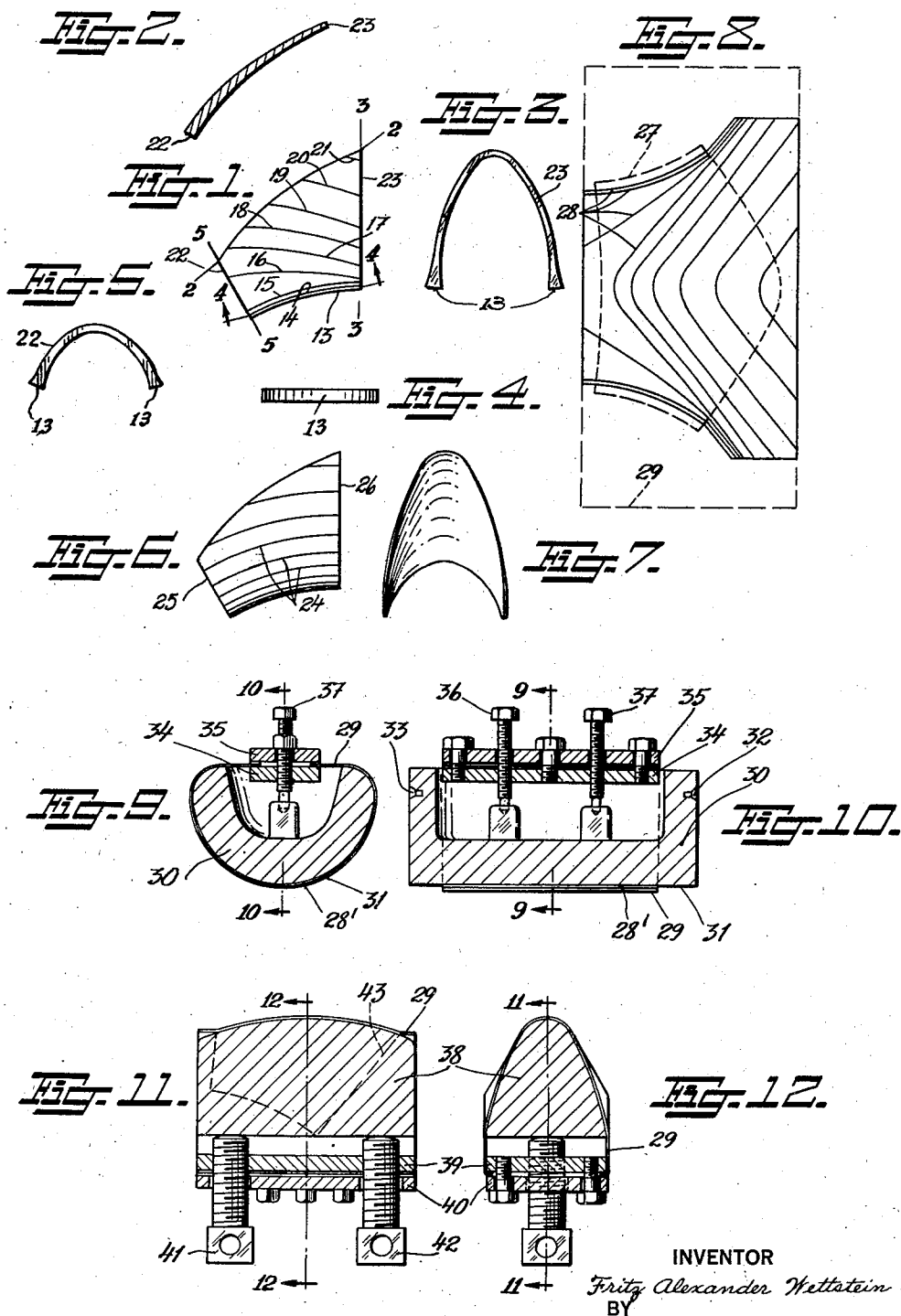
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F. A. WETTSTEIN

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METHOD OF MAKING ROTOR BLADES FOR STEAM OR GAS TURBINES

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METHOD OF MAKING ROTOR BLADES FOR
STEAM OR GAS TURBINESFritz Alexander Wettstein, Stockholm, Sweden,
assignor to Aktiebolaget Spontan, Stockholm,
Sweden, a corporation of SwedenApplication April 24, 1935, Serial No. 18,053
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This invention relates to rotor blades for steam and gas turbines and more particularly to blades of the type consisting of sheet metal shaped in the form of centrifugal catenary curves and having enlarged ends adapted to be retained in axially separated blade carriers, such as are disclosed in the U. S. patent to Ljungstrom, No. 1,942,608 and in my copending application, Serial No. 708,290, filed January 25, 1934, and issued January 21, 1936, as Patent No. 2,028,533.

It is one of the objects of the present invention to provide an improved construction for sheet metal blades of this type.

In comparison with turbine blades of conventional construction, rotor blades of the type to which the invention relates are very light, a condition which therefore makes it possible to construct rotor blade rims having much larger outlet areas and rotatable at materially higher peripheral speeds than ordinary blades. As is well known, this is particularly important for the low pressure portion of steam or gas turbines, and makes it possible to build relatively large, high speed units with a single outlet. However, it is not possible to reduce the thickness of these sheet metal blades at will, because the blades may tend to flutter under high loads. Tests have shown that fluttering may advantageously be eliminated by making the breadth of the blades in the peripheral direction as large as possible, i. e., by reducing the number of blades per rim to a minimum as for example to twelve blades per rim.

The invention has especial relation to this type of wide arched blade, and it is an object thereof to further reduce the centrifugal load exerted by the blades but without decreasing the resistance of the blades to fluttering.

Another object is to provide a blade of novel construction which will result in a substantially uniform distribution of the load on the blade carrier created by centrifugal force.

A further object is to so construct a blade of the character described that the centrifugal forces arising upon rotation produce a substantially constant stress in the material of the blade, and that the stress adjacent the blade base remains within allowable limits.

Still another object is to provide a turbine rotor blade of the arched type which is more resistant to fluttering than those hitherto known.

These objects are attained in the present invention by reducing the thickness of the blade in the direction from the inlet to the outlet edges. Arched blades which are relatively wide in the

peripheral direction are of less radial height at the inlet edge than at the outlet edge, as a result of the blade angle. It is obvious that, by increasing the blade thickness at the inlet edge or by decreasing it at the outlet edge, the centrifugal force exerted by the blades may be reduced, the weight of the blade remaining constant. At the same time, as a result of the increased blade thickness at the inlet edge, the resistance of the blades to fluttering is appreciably increased. The invention thus makes it possible to construct blade rims with still greater outlet areas and higher peripheral speeds, and thus makes it possible to build correspondingly larger turbine units.

Since to produce a blade of varying thickness by the ordinary processes and devices now known to the art would be both difficult and expensive, it is a further object of the invention to provide a new and improved method for constructing a turbine rotor blade of the arched type which is relatively simple in its procedural steps, requires a minimum of apparatus for its operations and is capable of readily producing blades of any desired configuration and thickness.

Still another object is to provide apparatus of novel construction for carrying out this improved method.

Further objects, features and advantages of the invention will become apparent upon consideration of the detailed description of the invention which follows. Although two different forms of the blade and only one embodiment of the method and apparatus of the invention are described and illustrated in the accompanying drawing, it is to be expressly understood that the drawing is for purposes of illustration only and is not to be construed as defining the limits of the invention, reference being had to the appended claims for this purpose.

In the drawing, wherein like reference characters indicate like parts throughout the several views:

Figs. 1 to 5 show one form of arched blade constructed in accordance with the present invention, the blade thickness being shown on a greatly exaggerated scale for the sake of clearness. Fig. 1 is a side view of the blade, viewed in the direction of the turbine axis. Fig. 2 is a cross section at right angles to the turbine axis (or to a line joining corresponding points of the blade ends) through the middle of the blade. Fig. 3 is an end view along line 3—3 of the blade outlet edge. Fig. 4 is a bottom view along line

4-4 of one of the blade bases. Fig. 5 is an end view along line 5-5 of the blade inlet edge.

Figs. 6 and 7 illustrate a second exemplary embodiment of an arched blade according to the invention, Fig. 6 being a side view and Fig. 7 an end view looking from the outlet end.

Figs. 8 to 12 illustrate a method of and apparatus for making blades according to the invention. Fig. 8 is a view of the blank used in producing a blade of varying thickness. Figs. 9 and 10 show a tensioning device used in working the blade sheet, Fig. 9 being a section along line 9-9 of Fig. 10 and Fig. 10 being a section along line 10-10 of Fig. 9 with the blade sheet and backing member shown in full.

Figs. 11 and 12 show a drawing device for imparting the final dished form to the arched blades, Fig. 11 being a section along line 11-11 of Fig. 12, and Fig. 12 being a section along line 12-12 of Fig. 11, the blade again being shown in full.

Line 13 in Fig. 1 represents the bottom edge or base of each end of an arched blade. In the present case, as shown, the blade bases are arcuate in form in side elevation and are adapted to be secured in corresponding grooves of annular blade carrier rings, not shown in the drawing. Lines 14-21 drawn on the blade surface represent lines of the same blade thickness. The blade thickness decreases from the bottom edges 13 outwardly, the difference in thickness between each two successive lines shown being equal. It is apparent from the extent of the lines of equal thickness that the blade inlet edge 22 is appreciably thicker than the blade outlet edge 23, as shown in Figs. 3 and 5 wherein, as above stated, the blade thickness is on a greatly exaggerated scale for the sake of clearness. On the other hand, it is evident from Fig. 4 that along the entire length of the base 13 the blade is preferably made of constant thickness. The section shown in Fig. 2, which is taken on a plane perpendicular to the turbine rotor axis (or to a line joining corresponding points of the blade ends) and passing through the center or crest of the blade, clearly shows the gradually decreasing blade thickness from the blade inlet edge 22 to the blade outlet edge 23. Sections taken on all other planes parallel to that of Fig. 2, except those immediately adjacent the blade bases, will obviously show similar variations in blade thickness between the inlet and outlet edges.

As shown in Figs. 3 and 5, the arc formed by the blade inlet edge is substantially shorter or shallower than that of the outlet edge 23. This difference in curvature is particularly great with blades which are relatively wide in the peripheral direction of the rotor, i. e. the blade base 13 of which is relatively long. This fact and the blade angle at the middle or highest point of the blade produce the appreciable difference in the height of the blade between the inlet and outlet edges. If the blade were made of the same thickness throughout in conventional manner, then upon rotation of the blade an appreciably greater centrifugal force would be exerted on the blade carrier at the point of attachment of the outlet end of the blade than at that of its inlet end. On the other hand, a proper distribution of the blade thickness, i. e. a correlated positioning of the lines of like blade thickness 14-21, makes it possible to obtain a uniform or substantially uniform centrifugal loading of the blade carrier throughout the entire length of the blade base 13. Since, for constructional reasons, it is desirable that the thickness of the blade base 13 remain unchanged

along the entire length thereof, this results in a constant load on the blade base. It is also apparent that a corresponding increase in the blade thickness toward the inlet edge and decrease toward the outlet edge will cause the blade to exert a smaller centrifugal force, the blade weight remaining the same, since the result is to make thinner and lighter those blade parts which are disposed on the large radii and which therefore move at the greater linear speeds.

The above described distribution of the blade thickness is also of great importance from the standpoint of the resistance of the blade to fluttering. As is well known, fluttering of turbine blades, aircraft wings, etc., is apparently due to a superposed transverse and torsional oscillation, whereby the blade or wing constantly absorbs energy from the medium flowing therearound. By making the relatively lower portion of the blade on the side of the inlet edge of relatively greater thickness, great rigidity is imparted to the blade at this point. This renders the appearance of a lateral oscillation at this point difficult; and since an oscillation of the outlet edge alone cannot produce fluttering, it is thus difficult for fluttering to take place. Another advantage of the relatively large blade thickness at the inlet edge resides in the fact that it minimizes the importance of the blade erosion which occurs at this part of the blade.

In the modification shown in Figs. 6 and 7, lines 24 again represent lines of like blade thickness. In this illustration, as shown, the lines of like blade thickness are disposed on cylindrical surfaces concentric with the turbine axis, i. e. the blades are of constant thickness at all points equidistant from the axis of rotation, the thickness diminishing with an increase in said distance from the axis. In this embodiment, as in that of Figs. 1-5, it is evident that the inlet edge 25 is of relatively greater blade thickness than the outlet edge 26. Of course, it will be understood that the blade of the present invention may be varied in thickness in many different ways. The essential thing is that the blade thickness in the direction of the flow of the driving medium passing through the blades decreases from the inlet to the outlet edge. At the same time, in this embodiment, the blade thickness preferably decreases from the blade base outwardly so that the centrifugal forces which arise upon rotation produce a substantially constant stress in the blade material, or that the blade stress adjacent the blade base remains within allowable limits.

Arched blades constructed in accordance with the present invention are preferably made from sheet metal rolled to a uniform thickness. It is evident that the production of the variable blade thickness in the desired distribution throughout the entire blade would be difficult and time-consuming with the aid of ordinary processes. It is therefore one of the objects of the present invention to provide a novel process and apparatus whereby the sheet metal to be used in making the blade is readily brought to the desired thicknesses. This process and apparatus are illustrated, by way of example, in Figs. 8-10.

Broken line 27 in Fig. 8 represents an arched blade in extended or developed form in a single plane, line 29 indicating the piece of sheet metal from which the blade is to be made. Whole lines 28 again represent lines of like blade thickness and correspond in position to lines 14-21 of Fig. 1. As shown in Fig. 8, lines 28 are extended beyond the limits of blade 27. According to the

of the remainder of the plate which is in direct contact with the supporting surface, and then removing sufficient metal from said outwardly projecting portions to render the entire outer surface of said plate parallel to said supporting surface.

5. A method of making a turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of interposing between said plate and the outer surface of a supporting member a backing member of varying thickness, tensioning the plate against the outer surface of said backing member and securing said plate to said supporting member in tensioned condition, and then removing metal from the outer surface of said plate until the same is parallel to the outer surface of said supporting member.

6. A method of making a turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of interposing between said plate and the outer surface of a supporting member a plurality of superposed pattern sheets of varying areas forming a backing member of varying thickness, tensioning the plate against the outer surfaces of said superposed pattern sheets, and securing said plate to said supporting member in tensioned condition and then removing metal from the outer surfaces of said plate until the same is parallel to the outer surface of said supporting member.

7. A method of making a turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of drawing the plate under tension about a backing member the surface of which in contact with the plate is so formed that the distance between certain points thereon and a cylindrical datum surface lying inwardly from said surface of the backing member corresponds to the decrease in plate thickness which it is desired to effect in the portions of the plate overlying said points, fixing said plate relatively to said datum surface in tensional condition, rotating the backing member and plate about the axis of generation of said datum surface, and removing sufficient metal from the plate during rotation to render its outer surface parallel to said datum surface.

8. A method of making a turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of securing the plate to a mandrel having a plate supporting surface, interposing a backing member of varying thickness between said plate and the supporting surface of said mandrel, the thickness of said backing member at certain points corresponding to the decrease in thickness which it is desired to effect in the overlying portions of the plate, tensioning said plate about said mandrel and interposed backing member until said plate is in intimate contact with the underlying portion of said backing member or of the supporting surface of said mandrel, said plate being secured to said mandrel in tensioned condition, and then removing sufficient metal from the outer surface of said plate to render the same parallel to the plate supporting surface of said mandrel.

9. A method according to claim 8 wherein

the backing member consists of a plurality of relatively thin, superposed sheets of metal of varying areas, the outline of each of said sheets corresponding to a line of constant thickness in the blade to be formed from said plate.

10. A method of making a turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of bending the plate about a mandrel having a semi-cylindrical plate supporting surface, interposing a backing member of varying thickness between said plate and the supporting surface of said mandrel, the thickness of said backing member at certain points corresponding to the decrease in thickness which it is desired to effect in the overlying portions of the plate, tensioning said plate about said mandrel and interposed backing member until said plate is in intimate contact with the underlying portion of said backing member or of the supporting surface of said mandrel, securing said plate to said mandrel in tensioned condition, and then rotating said mandrel about the axis of said semi-cylindrical supporting surface while removing the metal from the outer surface of said plate to reduce said surface to that of a true cylinder parallel to said supporting surface.

11. A method of making a turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of superposing a plurality of relatively thin pattern sheets of varying areas upon a datum surface of an area at least equal to that of said plate to produce a backing member the outer surface of which is so formed that the distance between certain points thereon and said datum surface corresponds to the decrease in plate thickness which it is desired to effect in certain portions of the plate, bringing the plate into contact with the outer surface of said backing member and fixing said plate relatively thereto, and then removing sufficient metal from the plate to render its outer surface parallel to said datum surface.

12. A method of making a blade of varying thickness out of a plate of sheet metal of uniform thickness, including the steps of interposing between a sheet metal blank and the outer surface of a supporting member a backing member of varying thickness, tensioning the blank against the outer surface of said backing member and securing said plate to said supporting member in tensioned condition, and then removing metal from the outer surface of said blank until the same is parallel to the outer surface of said supporting member.

13. A method of making a blade of varying thickness out of a plate of sheet metal of uniform thickness, including the steps of interposing between a sheet metal blank and the outer surface of a supporting member a backing member of varying thickness, securing such blank with relation to the supporting member in contiguous engagement with the backing member, removing metal from the outer surface of said blank until the same is parallel to the outer surface of the supporting member, and then imparting to said blank the desired arched configuration of the completed blade.

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present process, patterns 28' of relatively thin sheet metal are first cut out according to the forms represented by lines 28, these patterns being limited as shown in Fig. 8, and then superposed on each other. This results, as shown, in a saddle-shaped member which, by using a pattern sheet of proper thickness, corresponds in thickness at its various points exactly to the amounts by which the thickness of the sheet metal used in making the blade is to be reduced.

As shown in Figs. 9 and 10, sheet 29 is next attached to a tensioning device consisting essentially of a semi-cylindrical body 30, the outer surface 31 of which is accurately cylindrical, and which is adapted to be rotatably mounted on two central bores 32, 33, as on a lathe. The blade sheet 29, is tightly clamped at both its ends between two plates 34, 35 carried by body 30, the superposed pattern sheets 28' being interposed between the cylindrical surface 31 and the blade sheet 29 to form a backing member of variable thickness. Then, by turning screws 36 and 37 which are threaded into plate 34 and thrust at their lower ends against the inner surface of body 30, the blade sheet 29 is tensioned and drawn into intimate contact with the outer surface of the backing member constituted by pattern sheets 28'. This causes the outer surface of the blade sheet 29 to be raised in certain portions to an extent corresponding to the amounts by which its original uniform thickness is to be decreased. Blade sheet 29 may then be readily brought to the desired variable blade thickness by means of a simple operation, such as turning or grinding, preferably while rotating the tensioning device 30 about the axis defined by bores 32, 33.

It is evident that this method may also be carried out in other ways and by the use of other apparatus. For example, the cylindrical support 30 may be replaced by a support of any other suitable form. In such a case, the superfluous blade sheet thickness may be eliminated by grinding, as before, or by any other suitable operation for producing the requisite surface on the free side of the blade sheet. Instead of producing the desired blade thickness by working off the superfluous sheet material, it is evident that this may also be done by rolling the blade sheet, in which case the latter is again placed over a suitable backing member. Of course, in this event, the backing member must be made of relatively very hard material or sheet metal in order that the rolling may reduce only the thickness of the blade sheet placed thereon.

After the blade sheet has been brought to the desired thickness, as above described, a further operation is necessary in order to impart thereto its final dished or arched form. As shown in Figs. 11 and 12, this may be accomplished by drawing the blade sheet 29 over a form or mandrel 38 the outer surface of which is provided with a shape corresponding to that of the finished blade. To this end, the blade sheet may be tensioned or clamped at its ends between plates 39 and 40. Then by tightening screws 41 and 42 which are threaded into plate 39 and thrust against mandrel 38, it is evident that the central portion of the blade sheet will be stretched until the entire extent thereof is drawn into intimate contact with the surface of mandrel 38, whereby it receives its final dished or arched configuration. The finished blade may then be produced by cutting it out of sheet 29 along dotted line 43. The desired configuration of the blade may also be produced by a combined drawing and pressing

operation, instead of by the aforescribed purely drawing operation.

It will be obvious that the present invention is not limited in its scope to the particular blade constructions, procedural steps and apparatus described and illustrated, but that various changes, in addition to those suggested above and which will now become apparent to those skilled in the art, may be made in the form, details of construction and arrangement of the parts, and in the steps of the method, without departing from the spirit of the invention. Reference is therefore to be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. A method of making an arched turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of bringing the plate into contact with and securing it to a supporting surface, spacing certain portions of said plate from said supporting surface by amounts corresponding to the decrease in plate thickness which it is desired to effect in said portions, whereby the outer surface of said plate in said portions projects beyond that of the remainder of said plate which is in direct contact with the supporting surface, removing sufficient metal from said projecting portions to render the outer surface of said plate parallel to the supporting surface, and then imparting the desired arched configuration to said plate to complete the blade.

2. A method of making an arched turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of bending the plate into substantially semi-cylindrical form, causing certain portions of said plate to project beyond a true cylindrical surface by amounts corresponding to the decrease in plate thickness which it is desired to effect in said portions, removing sufficient metal from said portions to restore the surface of said plate to a true cylindrical surface, and then imparting the desired arched configuration to said plate to complete the blade.

3. A method of making an arched turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of bringing the plate into contact with and securing it to a cylindrical supporting surface, spacing certain portions of said plate from said supporting surface by amounts corresponding to the decrease in plate thickness which it is desired to effect in said portions, whereby the outer surface of said plate in said portions projects beyond that of the remainder of said plate which is in direct contact with the supporting surface, removing sufficient metal from said projecting portions to render the entire outer surface of said plate cylindrical in form and parallel to said supporting surface, and then imparting the desired arched configuration to said plate to complete the blade.

4. A method of making an arched turbine rotor blade of varying thickness out of a plate of sheet metal of uniform thickness including the steps of bringing the plate into contact with and securing it to a supporting surface, interposing a backing member of varying thickness between said plate and said supporting surface, the thickness of said backing member at certain points corresponding to the decrease in thickness which it is desired to effect in the overlying portions of the plate, the interposition of said backing member causing the outer surface of the overlying portions of the plate to project beyond that