C. STEENSTRUP.

BLADE SECURING MEANS AND METHOD OF MAKING THE SAME.

APPLICATION FILED JUNE 27, 1919.

1,366,605.

Patented Jan. 25, 1921.

Fig. 1.

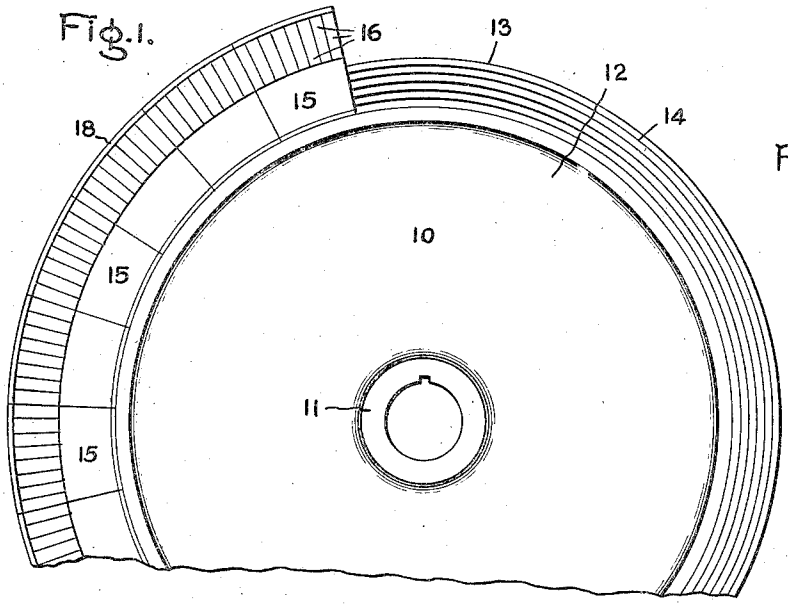


Fig. 2.

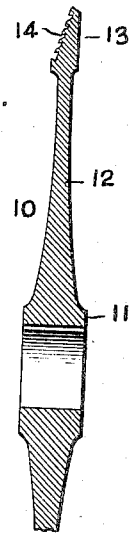


Fig. 3.

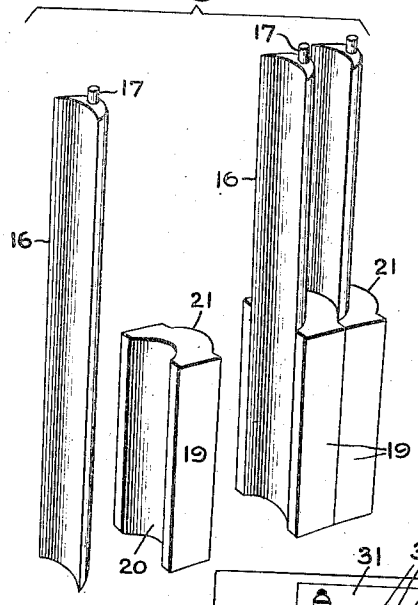


Fig. 4.

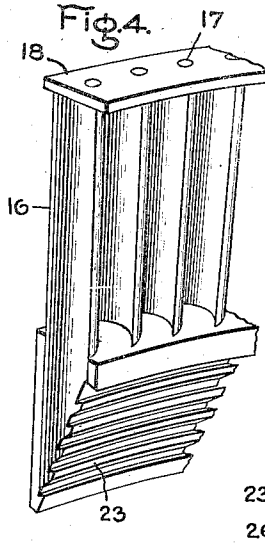


Fig. 5.

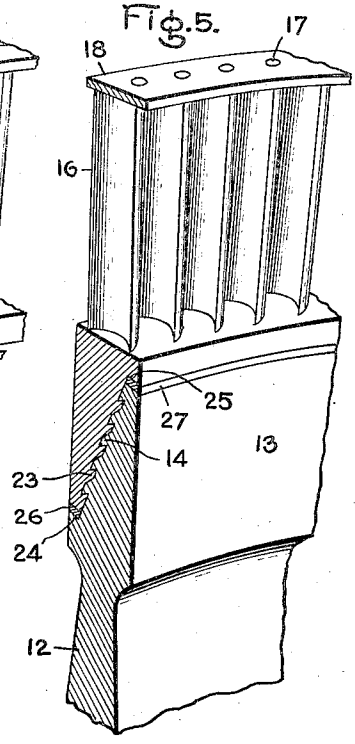
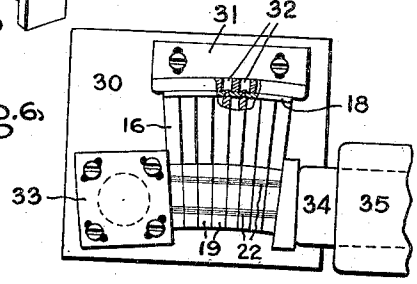


Fig. 6.



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by Albert G. Davis
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UNITED STATES PATENT OFFICE.

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BLADE-SECURING MEANS AND METHOD OF MAKING THE SAME.

1,366,605. Specification of Letters Patent. Patented Jan. 25, 1921.

Application filed June 27, 1919. Serial No. 307,184.

To all whom it may concern:

Be it known that I, CHRISTIAN STEENSTRUP, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Blade-Securing Means and Methods of Making the Same, of which the following is a specification.

The present invention relates to means for attaching what are variously known as blades, vanes or buckets of elastic-fluid turbines to their supporting wheel or rotors. The usual practice in turbines of the impulse type is to attach the blades to the wheel or rotor by means of dovetail connections. In some cases a dovetail projection is formed on the base of each blade which is inserted into a corresponding slot in the periphery of the rotor, while in other cases a dovetail projection is formed on the periphery of the rotor which is inserted into a corresponding slot formed in the base of each blade. In some cases individual space blocks are employed to separate the blades from each other to form working passages for the steam and in other cases the space blocks are formed integral with the bases of the blades. Such constructions have long been in use and in general are satisfactory where the strains due to centrifugal force are moderate and where the transfer of heat between the blades and their supports is not of material importance. Experience has demonstrated, however, that where the centrifugal strains or the temperature of the working fluid or both are high that such constructions are not satisfactory. From a mechanical point of view it is extremely difficult, if not impossible, to get the required strength in the base portion of the blade necessary to withstand high centrifugal stresses without making the parts unduly large which in turn necessitates much heavier rotating parts accompanied by a corresponding increase of the centrifugal stresses and in the over-all length of the machine.

In the manufacture of dovetail connections for turbine blades it is extremely difficult to get the workmen to properly fit the parts with the result that the blades are liable to and sometimes do work loose while the turbine is in operation resulting in injury to the machine. The greatest objection, however, resides in the fact that the completed structure has so many joints, each of which offers resistance more or less great to the flow of heat between the blades and the rotor. In the operation of an elastic-fluid turbine changes of load cause very wide changes of temperature to take place within the turbine, the low temperature of the vacuum frequently manifesting itself in the high pressure stages at light loads. This means a sudden cooling of the blades when the vacuum works back into the machine followed by an equally sudden heating of the blades when the load is restored. Due to the many joints and especially to the improper fitting of the parts changes of blade temperature are but imperfectly transmitted to the rotor resulting in distortions of the rotor or the blades or both. In some cases these distortions are not harmful while in others they are of such magnitude as to cause injurious rubbing or possibly wrecking of the machine.

I have invented or discovered an improved blade construction which is free of the objections above noted and which possesses marked advantages over any prior construction with which I am familiar, together with an improved method of making the same.

In the accompanying drawing which is illustrative of my invention, Figure 1 is a partial view in elevation of a blade carrying rotor; Fig. 2 is a cross-section of the same; Fig. 3 is a perspective view of blades and spacing blocks; Fig. 4 is a perspective view of a part of a blade element, segment or group; Fig. 5 is a perspective view of a rotor showing portions of a blade element, segment or group mounted in place, and Fig. 6 is a detail view showing the members of a blade group in a fixture in which they are temporarily bonded together.

10 indicates a rotor, having the usual hub 11, the latter having an opening for the shaft, not shown. 12 indicates the web of the rotor and 13 its rim. The rim is beveled on one side as best shown in Figs. 2 and 5 and formed thereon are undercut concentric projections 14 with grooves between. The projections and grooves are preferably small and numerous. The final machine cut can best be made with a specially formed tool to insure accuracy as to shape and finish. The blades are arranged

in elements, segments or groups 15 as best shown in Fig. 1 and each of said groups is individually removable.

The blade groups are formed in the following manner: The blades 16 are preferably formed of straight strips of the same section throughout their length since such a construction results in a material saving both in labor and stock. This also makes it possible to produce a far better and more uniform blade, than where individual blades are made with an enlarged fastening member at the root end. The blades may be made of steel or any other suitable material and have any suitable shape in cross-section. The blade stock is cut to the required length and a tenon 17 formed at the outer end to assist in securing the blade cover or shroud 18 in place. Between the roots of the blades are space blocks 19 for separating them by the proper distance so as to provide passages for the steam. The front wall 20 of each block is concave and corresponds in shape and size to the convex back of a blade. The back wall 21 of each block is convex and corresponds in shape and size to the concave or working face of a blade. The sides of the blocks preferably extend well beyond the sharpened edges of the blades on both sides so as to form a solid, substantial holding means. Since in an axial flow impulse turbine the blades extend radially from the shaft axis and since the blades are of uniform section, each space block is made thicker at its outer than its inner end to compensate for the fact that the outer end of the block is farther from the shaft axis than the inner end. In other words, when the blades are radially disposed the blocks are arranged to completely fill the spaces between them at their roots or inner ends. In some cases it may be desirable to concave the outer end of each space block so as to produce a fillet effect with the adjacent blades.

After a sufficient number of blades and blocks have been completed they are assembled in a jig or fixture to form an arc-shaped group or segment as shown in Fig. 6, the radius of the arc corresponding as nearly as possible to the radius of the finished group or segment, while in the fixture the blades and blocks are subjected to rather heavy endwise pressure and thereafter they are temporarily bonded or united in their pressed up state by suitable means. I have found arc or oxy-acetylene welding to be satisfactory for the purpose. For example, they may be united by one or more narrow arc welds or bonds extending along opposite sides of the blade roots and blocks as indicated at 22. These welds may be arranged in any desired manner; for example, they may be straight and form chords to the arc of the segment. After the members of group have been properly united by welding or other means, the cover or shroud 18 is placed in position with the tenons 17 projecting through the corresponding holes in the cover. It is not always necessary to provide a cover but good practice dictates its use. The next step is to unite the blades and space blocks, and a cover when used, in a solid or unitary whole. This is best done by copper brazing in a furnace in the presence of hydrogen or equivalent gas. A very small amount of copper suffices for the purpose. The arc welds or bonds securely hold the members of the group in place and the molten copper works into all the joints between the blades and blocks and between the cover and the ends of the blades and also between the tenons and the surrounding walls of the holes in the cover. By pulling tests I have ascertained that when parts are united in this manner the rupture takes place in the material itself instead of at the joints as might reasonably be expected. I have also ascertained that the presence of the small amount of copper necessary in brazing two pieces of steel together appreciably increases the strength of the steel. This is probably due to the fact that the copper by reason of the intense heat in the furnace penetrates the surface of the blades for a short distance and alloys with the steel. After the brazing operation the blades and space blocks are for all intents and purposes one solid mass and hence all danger due to loose blades is obviated. It also follows from this that the heat conductivity between the blades and space blocks is as good as it is possible to make it.

The next step is to finish the ends of each group or segment in radial planes after which a sufficient number to blade a rotor are mounted in a circle on a suitable machine, as a boring mill, for example, and one side surface of the blade elements beveled to correspond to the beveled surface on the rotor. I next form concentric undercut locking projections 23, said projections being identical in shape and size with those on the rotor itself so that when assembled in place the parts will interlock. To insure accuracy in the machine operation the same tool is employed to finish the projections and grooves that is employed for the purpose in finishing the rotor. Since the blades extend to the bottom of the space blocks it follows that the undercut projections are formed in each of the blades as well as in each of the space blocks, all of which aids in making a good mechanical fastening and in insuring good heat conductivity between the blades, blocks and rotor.

As will appear from Fig. 5 the parts are so machined that when assembled small undercut circumferential slots are left at points 24 and 25. Owing to the fact that the projections are undercut some radial

clearance is necessary at these points to permit the parts to be assembled but I make the slots undercut and of greater radial depth than is necessary for this purpose. In the slots are located calking and shearing strips of metal 26 and 27 which are calked into place by a suitable calking tool. The strip 26 is located between an annular shoulder on the rotor and the inner curved surface of each blade group and the strip 27 between the periphery of the rotor and an overhanging shoulder formed on the blade group. The effect of this calking operation is to force the locking projections into firm contact with each other at all points. Due to the fact that the slots thus formed are undercut as distinguished from extending parallel with the wheel axis, the blade elements cannot be forced out of their proper position in the plane of the wheel due to the action of the steam on the blades, without shearing the calking strips, and said strips are made of sufficient sections to prevent this from taking place. The undercut shoulders or projections also serve to prevent displacement. It will thus be seen that each blade group is mechanically held in position by two means, *i. e.*, by the undercut projections and by the calking and shearing strips. Instead of using calking strips I may unite the blade groups and rotor by filling the slots 24 and 25 with fused metal, using for the purpose an oxy-acetylene flame. In this latter arrangement a calking strip is in effect provided but it forms a unitary part of the complete rotor. The former arrangement has the advantage, however, that the strips can be dug out by a suitable tool when it becomes necessary for any reason to reblade a rotor wholly or in part. The inclined or beveled surfaces of the blade elements and rotor taken in connection with the undercut coöperating projections cause the parts always to tend to move into closer contact rather than the reverse with the advantage of improving the heat exchange between the blade elements and the rotor proper.

It will also be noted that each group of blades in addition to being held in position by the interlocking projections is held by two locking means, *i. e.*, the shearing and calking strips 26 and 27 which are situated on opposite sides of the rotor and at different radial distances from the shaft axis. This disposition of the locking means affords a much better arrangement to resist lateral deflection of the blade groups due to the action of the steam than would be the case if they were situated at the same radial distance from the shaft axis. Preferably all the machine work on the groups of blades is completed before they are mounted on the rotor.

It is also to be noted that the sides of the blade groups occupy the same planes as the sides of the rotor and hence the rim of the rotor as a whole can be made relatively narrow, a feature of importance because it reduces to a minimum the overall length of the turbine, it being understood that it is customary to employ a large number of bladed rotors in the same turbine, each rotor being located in a separate compartment or stage in the casing.

Referring to Fig. 6, I have shown a type of fixture suitable for assembling a group of blades and space blocks preparatory to copper brazing them. 30 indicates a foundation plate and adjustably mounted thereon is an L-shaped member 31 whose under side is curved on the same radius as the tips of the blades. In the member are holes 32 registering with the blade tenons and through which a tool can be inserted for riveting over said tenons. 18 indicates the blade cover through which the blade tenons project; 16 indicates the blades and 19 the space blocks. The blades and blocks are assembled in the manner shown between an adjustable stop 33 and the ram 34 of a hydraulic ram 35 of any suitable construction. After the parts are assembled the ram subjects them to endwise pressure, after which the blocks are temporarily united by arc or other welds indicated at 22 and the blade cover secured in place by riveting over the blade tenons. The group thus formed is then removed from the fixture, turned over and the back side of the space blocks bonded by arc or other welding.

It is to be particularly noted that as a result of the above described machine operations, all of the coöperating surfaces are surfaces of revolution and hence when the undercut projections of the blade group or segment and of the rotor are in engagement the exchange of heat between the blade segment or element and the rotor will be as complete as it is possible to make it in any jointed structure. Furthermore, by the use of a plurality of coöperating undercut projections I am able to obtain a mechanical union between the blade elements and the rotor which is very much stronger than is possible to obtain in any dovetail constructions in which the size and weight of the blade elements and rotor are approximately the same. This arrangement of concentric interlocking projections also forms a very effective means for transmitting the torque exerted by the blades to the rotor.

My improved construction has the further and material advantages that a large number of joints are obviated and that all danger of the individual blades working loose is overcome because the blades and space blocks of each group are united into a unitary mass by the copper brazing process. Also that all joints between the blades and

spacing blocks are avoided with the result of greatly improving the heat conductivity.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. The method of manufacturing a rotor having a blade ring thereon which comprises forming a number of arc-shaped segmental groups by assembling a plurality of blades and spacing devices into an arc-shaped segmental group and uniting them into a unitary mass by fusion of metal, and then fastening said groups individually on the rotor to form a ring of blades thereon.

2. The method of forming blade elements for elastic-fluid turbines which comprises assembling a plurality of blades and spacing devices into an arc-shaped group substantially conforming in shape to that of the finished product, uniting them into a unitary mass, beveling one face of the element thus formed, and cutting concentric projections in said beveled face.

3. The method of forming blade elements for elastic-fluid turbines which comprises assembling a plurality of blades and spacing devices into an arc-shaped group substantially conforming in shape to that of the finished product, uniting them into a unitary mass, beveling one face of the element thus formed, and cutting a plurality of relatively small undercut projections in said beveled face.

4. The method of forming blade elements for elastic-fluid turbines which comprises assembling a plurality of blades and spacing devices into an arc-shaped group, subjecting the parts to endwise pressure, bonding the assembled parts to hold them in position, and subsequently uniting them into a unitary mass by the application of heat and of fused metal.

5. The method of forming blade elements for elastic-fluid turbines which comprises assembling a plurality of blades and spacing devices into an arc-shaped group substantially conforming in shape to that of the finished product, subjecting the assemblage of parts to endwise pressure, and copper brazing said parts to form a unitary mass.

6. The method of forming blade elements for elastic-fluid turbines which comprises assembling a plurality of blades and spacing devices into an arc-shaped group substantially conforming in shape to that of the finished product, subjecting the assemblage of parts to endwise pressure, copper brazing said parts to form a unitary mass, beveling one face of the base portion of the element thus formed, and cutting concentric projections in said beveled face.

7. The method of forming blade elements for elastic-fluid turbines which comprises assembling a plurality of straight blade lengths and tapered space blocks into an arc-shaped group substantially conforming in shape to the finished product, uniting them into a unitary mass, beveling off one side of the blades and space blocks, and cutting concentric projections in the beveled faces of the blades and blocks.

8. The method of blading a turbine rotor which comprises assembling a plurality of blades and spacing devices into unitary groups, beveling the side faces of the groups and forming concentric undercut projections in the faces, beveling the side face of the rotor, and forming undercut projections in the face which engage those on the blade groups, and locking the groups on the rotor.

9. In combination, a turbine rotor, and a number of segmental blade groups individually fastened thereon to form a blade ring, each blade group comprising a plurality of blades and spacing devices united by fusion of metal to form a unitary mass.

10. In combination, a turbine rotor, a blade system therefor, said blade system being divided into arc-shaped groups, each of which comprises a plurality of blades of uniform section throughout their length with space blocks between their roots, said blades and blocks being brazed together to form a unitary mass, and means for securing the groups to the rotor.

11. In combination, a rotor having concentric undercut annular projections with arc-shaped blade groups, each comprising individual blades and spacing devices united to form a unitary mass, each of said groups having concentric undercut annular projections which engage corresponding projections on the rotor, and retain said groups against the effects of centrifugal force.

12. In combination, a turbine rotor having a beveled side face with a plurality of concentric projections on said face, a plurality of arc-shaped blade groups, each group having a beveled side face with concentric projections which engage those on the rotor, and means for locking the blade groups to the rotor.

13. In combination, a turbine rotor having a beveled side face with a plurality of concentric projections on said face, a plurality of arc-shaped blade groups, each group having a beveled side face with concentric projections which engage those on the rotor, and a means on each side of the rotor for locking the blade groups thereto.

14. In combination, a turbine rotor having a beveled side face with a plurality of concentric projections on said face, a plurality of arc-shaped blade groups, each group having a beveled side face with concentric projections which engage those on the rotor, and a means which serves to hold said projections in mutual engagement and also resist lateral stresses on the blades when they are subject to the action of motive fluid.

15. In combination, a turbine rotor having a beveled side face with a plurality of concentric projections on said face, a plurality of arc-shaped blade groups, each group having a beveled side face with concentric projections which engage those on the rotor, and a means on each side of the rotor for locking the blade groups thereto, said means being located at different radial distances from the axis of the rotor.

16. In combination, a turbine rotor having a beveled side face with a plurality of concentric undercut projections on said face, a plurality of blade elements, each element having a beveled side face with concentric undercut projections on said face which engage those on the rotor, and means for locking the individual blade elements to the rotor.

17. In combination, a turbine rotor having a beveled side face with a plurality of concentric projections thereon, a plurality of arc-shaped blade groups, each comprising blades and spacing blocks brazed to form a unitary mass and having a beveled side face with concentric projections thereon which engage the projections on the rotor, and means located on opposite sides of the rotor for locking the blade groups thereto.

18. In combination, a turbine rotor having a beveled side face which has concentric undercut projections, blades therefor, each of which has a beveled side face and concentric undercut projections arranged to engage the rotor projections, and calking and shearing strips which are inserted between the periphery of the rotor and the blades on one side thereof and between the inner annular surface of the blades and an annular shoulder on the rotor on the other side.

19. In combination, a turbine rotor having a beveled side face with undercut projections thereon, blades for the rotor having bases which are correspondingly beveled and have undercut projections which engage those on the rotor, and means exerting radial pressure for holding said projections in contact.

20. In combination, a turbine rotor having a beveled side face with concentric undercut projections thereon, which extend generally in an axial direction, blades for the rotor having bases which are correspondingly beveled and have concentric undercut projections which engage those on the rotor, and means located at the upper and lower ends of the bases for holding said projections in firm contact.

21. In combination, a turbine rotor having a beveled side face with concentric undercut projections thereon, blades for the rotor, space blocks located between the root ends of the blades, the blades and blocks being beveled on one side to correspond with the beveled face of the rotor and having concentric undercut projections which engage those on the rotor, and calking means for holding the undercut projections in contact.

22. A blade for an elastic-fluid turbine which is of uniform section throughout its length, in combination with a space block which is brazed to the root end of said blade and is tapered from end to end.

23. In combination, a turbine rotor having a plurality of concentric projections arranged on one side thereof near its periphery, blades and space blocks arranged in unitary groups, each group having projections which engage those on the rotor, and means arranged at different radial distances from the axis of the rotor and on opposite sides of said rotor for holding said blade groups in position.

In witness whereof, I have hereunto set my hand this 26th day of June, 1919.

CHRISTIAN STEENSTRUP.