April 30, 1957 A. W. RANKIN 2,790,620

MULTIPLE FINGER DOVETAIL ATTACHMENT FOR TURBINE BUCKET

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Fig. 1.

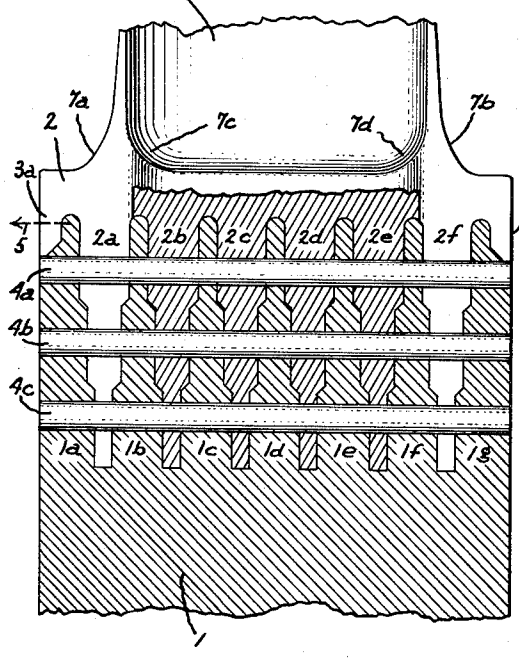


Fig. 2.

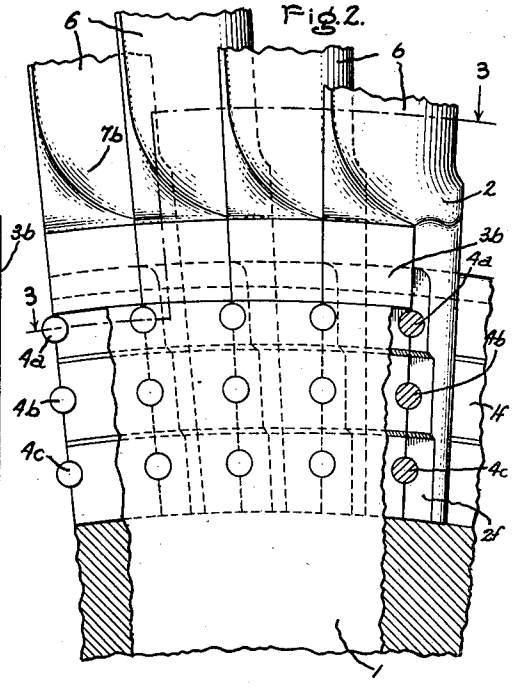


Fig. 4.

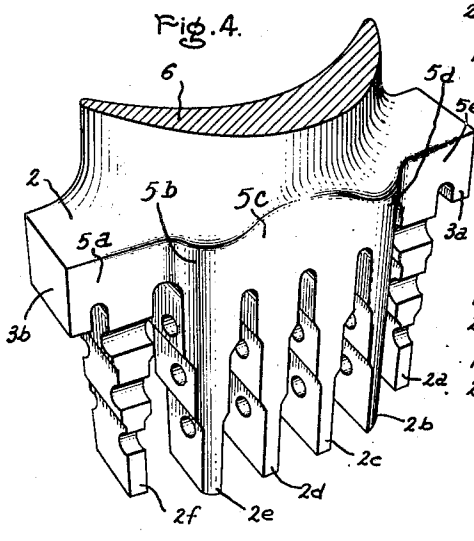
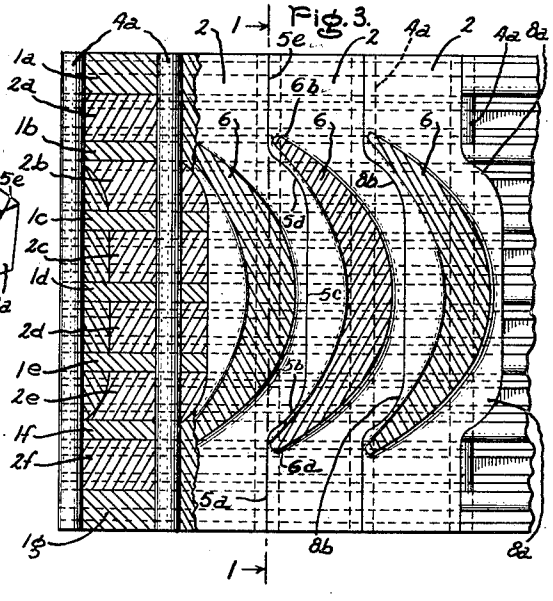


Fig. 3.



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MULTIPLE FINGER DOVETAIL ATTACHMENT FOR TURBINE BUCKET

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3 Claims. (Cl. 253—77)

This invention relates to an improved dovetail type of attachment for axial flow turbine buckets, particularly to the type of dovetail in which the turbine bucket and wheel rim have a plurality of interleaved finger members through which pass a number of axial dowel pins.

In large capacity elastic fluid turbines, for instance high pressure steam turbines in the range above 50,000 kilowatts, the last-stage buckets may become as long as 26 inches, active length, weighing on the order of 12 pounds each, and having a centrifugal force on each exceeding 100,000 pounds in normal operation. The problem of attaching such large buckets to the rotor thus becomes of major importance. One fairly common bucket attachment involves providing the wheel rim with a plurality of parallel circumferentially extending grooves, each bucket having a plurality of mating tapered "fingers" adapted to be assembled in interleaved relation with the circumferentially extending "tongues" defined by adjacent grooves in the wheel rim, each bucket base being locked to the wheel by a plurality of transversely extending dowel pins passing through the respective bucket fingers and wheel rim tongues. Because of the deeply curved shape of the blade portion of the bucket, it has sometimes been found necessary to design the blade so the inlet and discharge edges of the blade "overhang" the bucket base, in order to get the desired bucket-to-bucket spacing. This renders particularly difficult the task of designing the bucket so that excessive stresses in the comparatively thin edge portions will not induce failures.

Accordingly, a purpose of the present invention is to provide an improved "pinned-tongue-and-finger" type of turbine bucket dovetail which not only permits eliminating the thin overhanging inlet and discharge edges of the blade, but gives sufficient room on the base, along both the concave and convex sides thereof, for a generously proportioned curved fillet to increase the fatigue strength of the bucket at the juncture between blade and base.

Another object is to provide an improved pinned dovetail bucket attachment structure in which the dowel pins not only lock the buckets to the wheel rim but also serve to key adjacent buckets to each other.

A still further object is to provide an improved dovetail bucket attachment of the type described in which all buckets on a given wheel may be identical.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawing, in which Fig. 1 is a longitudinal sectional view of a pinned multiple finger dovetail in accordance with the invention, Fig. 2 is an elevation view of a segment of the bucket-wheel showing several adjacent buckets, Fig. 3 is a sectional view of a bucket assembly including several adjacent buckets, viewed in a radial direction substantially parallel to the portions 5*a* and 5*e* of the separation surface, as indicated by the offset line 3—3 in Fig. 2, and Fig. 4 is a perspective view of the base portion of a single bucket.

Generally stated, the invention is practiced by offsetting the middle portion of the bucket base in a circumferential direction relative to the respective side portions of the base, so the curved blade conforms generally to the shape of the base, the location of the dowel pins being so related to the respective offset portions of the bucket base that the loading on the pins in normal operation is entirely symmetrical.

Referring now more particularly to the drawings, as shown in Fig. 1, the wheel rim 1 is provided with six parallel grooves defining therebetween the respective circumferentially extending "tongues" 1*a*, 1*b*, 1*c*, 1*d*, 1*e*, 1*f*, 1*g*. The bucket base portion 2 has similar circumferentially extending grooves forming the mating "fingers" 2*a*, 2*b*, 2*c*, 2*d*, 2*e*, 2*f*. In addition, the base 2 has smaller side flanges 3*a*, 3*b*, the function of which will be seen hereinafter.

Each bucket base is locked to the wheel rim 1 by three radially spaced dowel pins 4*a*, 4*b*, and 4*c*. As will be appreciated by those familiar with this general type of turbine bucket attachment, the blade bases are carefully machined to fit the grooves in the wheel rim, and the holes for the dowel pins 4 are then drilled through both the fingers 2*a*, 2*b*, etc. and the tongues 1*a*, 1*b*, etc. and carefully reamed with the bucket in proper position relative to the wheel rim. Careful fitting of the dowel pins is very important in order that each finger and tongue will carry its share of the load.

It will also be seen in Fig. 1 that the respective fingers and tongues are tapered in discrete steps, there being one step for each dowel pin. The sides of the respective stepped portions of the fingers are parallel so that, in drilling the dowel pin holes, the drill encounters the separation plane between finger and tongue at right angles thereto. This enhances the accuracy of the drilling operation.

The function of the smaller side flanges 3*a*, 3*b* will be apparent from Fig. 1. When the joint is loaded by centrifugal force acting on the bucket in normal operation, the strong radially outward pull on the finger 2*a*, coupled with the opposite force on the tongue 1*a*, will produce a bending effect on the extreme end portion of dowel pin 4*a*. The result is that the end of the pin tends to bend downward, toward the axis of the wheel, and the extreme outer portion of the tongue 1*a* tends to deflect axially away from the finger 2*a*, as indicated by the dotted arrow 5 in Fig. 1. The function of the small side flanges 3*a*, 3*b* is to prevent such axial deflection of the end tongues 1*a*, 1*g*.

As also seen in Fig. 1, the blade portion of the bucket, only a portion of which is indicated at 6 in Fig. 1, is provided with curved fillets 7*a*, 7*b*, 7*c*, 7*d* at the juncture of the blade with the base 2. This is important from the standpoint of stiffening the bucket against vibration of the blade, as well as to increase the fatigue strength of the juncture between the comparatively lighter blade section and the more massive base section.

Fig. 2 shows a side elevation view of several adjacent buckets. Here it will be seen that the blade is generally crescent-shaped in cross section and that the overall circumferential dimension of each base portion 2 is equal to the maximum circumferential depth of the blade portion 6, so that there are no "overhanging" blade portions without direct connection to the base.

Fig. 3 represents a top view of the assembled bucket bases 2 with the blades 6 shown in section. From a comparison of Fig. 3 with the perspective view of Fig. 4, it will be apparent that the side fingers 2*a*, 2*f* of the bucket base are "offset" in a circumferential direction relative to the four intermediate fingers 2*b*, 2*c*, 2*d*, 2*e*. Fig. 3 shows how this offset configuration makes the deeply

curved blade 6 more nearly conform to the shape of the supporting base 2. It will be apparent that the offset base projects out beyond the outline of the curved blade sufficiently, on both the front and back sides of the blade, as to provide for the curved fillet between blade and base.

It will be seen that this construction results in a characteristic offset base shape, the plan view of which may be seen in Figure 3. The irregularly curved "separation surface" defined between abutting bucket bases is the same in all cases, since all buckets are of identical shape. This separation surface includes a first portion identified 5*a* which extends from the side of the rotor in an axial direction a substantial distance, along the axially extending side surfaces of the flange 3*b* and the side finger 2*f*, to a location closely adjacent the entrance edge portion 6*a* of the blade. The separation surface then curves sharply at 5*b* to substantially follow the curvature of the convex side of blade portion 6*a*. The next portion 5*c* of the separtion surface extends axially, along the axially extending side surfaces of the middle fingers 2*d*, 2*c*, and approaching closely to the convex surface of the abutting blade, as will be obvious from Figure 3. This portion 5*c* of the separation surface continues axially to a location close to the concave surface of the blade, then curves sharply at 5*d* to substantially follow the concave surface of the blade exit edge portion 6*b*. The terminal portion of the separation surface identified 5*e* extends axially past the adjacent blade edge portion 6*b* and continues axially along the axially extending side surface of the other side finger 2*a* and side flange 3*a* to the other side of the rotor. Thus it will be apparent that the invention provides a bucket base of substantially constant circumferential thickness throughout its axial width which conforms generally to the crescent shape of the blade, yet is comparatively easy to manufacture.

It is of particular importance to note the disposition of the dowel pin holes relative to the offset fingers 2*a* and 2*f*. The intermediate fingers, 2*b*, 2*c*, 2*d*, 2*e* are of substantially similar cross-section, at any given radius, except for the fact that the fingers 2*b*, and 2*e* are somewhat rounded off, corresponding to the curves 5*d*, 5*b* in Fig. 3. More specifically, the center fingers 2*c*, 2*d* are of rectangular cross-section; whereas, the fingers 2*b*, 2*e* have a parallelogram cross-section, by reason of the curved end portions 5*d*, 5*b*.

As may be readily seen in the perspective view of Fig. 4, and as represented by the dotted line showing of the dowel pin holes in Fig. 3, each set of dowel holes is carefully located so as to pass almost exactly through the middle of the intermediate fingers 2*b*, 2*c*, 2*d* and 2*e*. This is important in order that centrifugal force acting on the blade will cause the base to impose symmetrical loading on the respective portions of the several dowel pins. This symmetrical disposition of the dowel pins relative to the circumferential width of the attachment fingers reduces the tendency of the bucket to deflect in a circumferential direction about the axis of the dowel pins, when loaded.

Whereas the dowell pins pass as nearly as possible through the middle of the intermediate fingers in the side fingers 2*a*, 2*f*, each dowell pin is disposed in a circular opening formed half in one finger and half in the abutting finger of the next adjacent bucket. This will be obvious from a consideration of Fig. 2. It is to be noted that exactly half of the hole is formed in each adjacent blade base.

It will be seen that the above-described disposition of the dowel pin holes means that the offset side portions of the blade base 2 are displaced circumferentially from the intermediate base portion by an amount equal to exactly half the circumferential thickness of the bucket base.

An important advantage of this dowel pin arrangement is that, in the side fingers 2*a*, 2*f*, each pin serves as a "key" locking a given finger to the next adjacent finger. This increases the resistance of the bucket to what is known as "single bucket failure." Assume for instance that, by some accident of chance, three dowel pins of below standard strength should be assembled in the same bucket base. This substandard joint would tend to fail first. However, because of the above-described keying action of the end portions of the dowel pins engaging the semi-circular recesses in the respective adjacent side fingers, the weak bucket tends to be supported by each adjacent bucket. Since it is extremely unlikely that there would be two adjacent buckets with dowel pins of substandard strength, any such weak bucket connection will be reinforced by the keyed connection to the adjacent stronger buckets.

Thus my improved offset bucket base arrangement provides an important improvement in resistance to "single bucket failure." This is in addition to the very substantial improvement in resistance to vibration and fatigue strength of the blade, due to the fact that there are no overhanging portions relative to the base and due to the curved fillet portions which may be readily provided on both the convex and concave sides of the blade at the point of connection to the base.

A further important advantage of the construction lies in the fact that all buckets are identical. That is, the disposition of the dowel pin holes is the same in each bucket. This is a tremendous advantage from the standpoint of cost of manufacture and ease of assembly. Also, as noted above, the symmetrical disposition of the dowel pin holes results in an important strengthening of the construction. The accuracy of the critical drilling operation for the dowel pin holes is improved by the fact that at no point does a dowel pin hole have to traverse a curved or slanted surface separating the bucket finger from the wheel tongue. This advantage is apparent from the perspective view of Fig. 4, where it may be clearly seen that each hole penetrates cleanly through a surface which is exactly normal to the axis of the hole.

While only one bucket attachment structure in accordance with the invention has been described specifically herein, it will be obvious to those familiar with the turbine art that certain modifications may be made without departing from the invention. For instance, while the number of fingers on the blade base in the present example is six, fewer may be used for buckets of smaller axial width. Specifically, there may be a total of perhaps only three or four fingers, corresponding to two offset side fingers like 2*a*, 2*f*, and one or two intermediate fingers like 2*b*, 2*e*. It will also be apparent that there may be a greater number of fingers for buckets of still greater axial width, in which case there might be two fingers on each offset side portion, instead of the single fingers 2*a*, 2*f* shown herein. Likewise, the number of dowel pins used may vary, according to the loading, materials used, etc. While the invention has been described as a turbine bucket, it is obviously also applicable to compressors and like turbomachines.

Still other changes will occur to those skilled in the art, and it is of course intended to cover by the appended claims all such modifications as fall within the true spirit and scope of the invention.

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

1. A turbomachine bucket for a rotor with a circumferential row of identical buckets each comprising a blade of generally crescent-shaped cross-section secured to a base, said base being of substantially constant circumferential thickness throughout the axial width thereof and having a plurality of deep grooves extending circumferentially of the rotor when mounted thereon and defining in the base at least two side fingers and at least one additional middle finger axially spaced between said side fingers and adapted to be assembled in inter-

leaved relation with tongues formed by parallel circumferential grooves in the rotor, said side fingers being disposed at opposite sides of the base in a common plane axial of the rotor and displaced circumferentially relative to said middle finger by a distance substantially equal to half the circumferential thickness of the base, each base having sides so shaped that, when in assembled relation on the rotor, the radially extending separation surface between a leading blade and an adjacent following blade extends in a direction axial of the rotor from one side of the rotor a substantial distance and along the axially extending side surface of the side fingers of the bases of said adjacent blades to a location closely adjacent the entrance edge of the leading blade, then curves sharply to substantially follow the curvature of the concave side of said leading blade, then extends in an axial direction along the axially extending side surface of the middle fingers of said blade bases, approaching close to the convex surface of the following blade, and continuing axially to a location close to the concave surface of the leading blade, then curves sharply to substantially follow said concave surface of the leading blade to the exit edge portion of said leading blade, then extends axially past said leading blade exit edge portion and continues in an axial direction along the axially extending side surface of the other side fingers of the bases of said blades to the other side of the rotor, and a plurality of parallel dowel pins disposed in axial holes through the fingers of the base and the tongues of the rotor, the pins for each bucket being located in a common axial plane passing substantially through the middle of the middle finger while the respective end portions of each pin are disposed in semicircular recesses formed half in one side finger of the leading bucket base and half in the abutting finger of the adjacent following blade base.

2. A turbomachine bucket in accordance with claim 1 in which each finger of the bucket base tapers in thickness in discrete radially spaced flat-sided steps, the sides of each step being defined by parallel planes normal to the axis of the rotor, each dowel pin being located substantially at the center of one of said flat-sided steps in the middle finger.

3. A turbomachine bucket for a rotor with a circumferential row of identical buckets each comprising a blade of generally crescent-shaped cross-section secured to a base, said base being of substantially constant circumferential thickness throughout the axial width thereof and having a plurality of deep grooves extending circumferentially of the rotor when mounted thereon and defining in the base a side finger disposed at each side of the rotor and four axially spaced middle fingers disposed between the side fingers and adapted to be assembled in interleaved relation with tongues formed by parallel circumferential grooves in the rotor, said side fingers being disposed in a first common reference plane

axial of the rotor and displaced circumferentially relative to said middle fingers by a distance substantially equal to half the circumferential thickness of the base, the four middle fingers being disposed in a second common reference plane parallel to said first reference plane and including two center fingers of rectangular cross-section and at either side thereof a finger having an end portion of substantially parallelogram cross-section, the sides of the base being so shaped that, when in assembled position on the rotor, the radially extending separation surface between the bases of each pair of adjacent leading and following blades extends in a direction parallel to said reference planes from one side of the rotor a substantial distance and along the axially extending side surface of the side finger of the base of the leading blade to a location closely adjacent the entrance edge of the blade secured to that base, then curves sharply to substantially follow the curvature of the concave side of said entrance edge portion of the leading blade, said sharp curvature forming an inclined end surface of one of said fingers of parallelogram cross-section, the radial separation surface then extending parallel to said reference planes along the axially extending side surface of the two center fingers of rectangular cross-section and approaching close to the convex surface of the abutting following blade, continuing in a direction parallel to said reference planes to a location close to the concave surface of said leading blade, then curving sharply to substantially follow said concave surface to the exit edge portion of said leading blade, said last-mentioned sharp curvature forming the inclined end surface of the other of said fingers of parallelogram cross-section, the separation surface then extending axially past said leading blade exit edge portion and continuing a substantial distance in a direction parallel to said reference planes and along the axially extending side surface of the other side finger to the other side of the rotor, and a plurality of parallel dowel pins disposed transversely through holes in the fingers of the base and the tongues of the rotor, the pins for each bucket being located in a common radially extending plane passing substantially through the middle of the middle fingers and parallel to said first reference plane, while the respective end portions of each pin are disposed in semicircular recesses formed half in one side finger of the leading blade base and half in the abutting side finger of the following blade base.

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