July 14, 1959 D. J. BLOOMBERG 2,894,318

TURBOMACHINE BUCKET-WHEEL FABRICATED BY CASTING

Filed Oct. 8, 1952 3 Sheets-Sheet 1

Fig. 1.

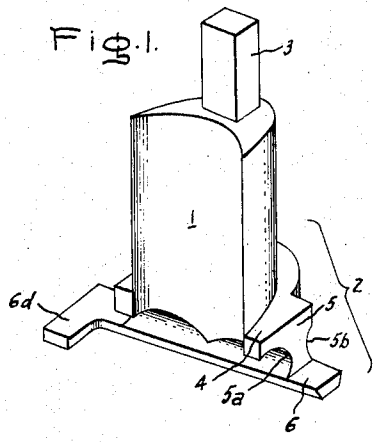


Fig. 2.

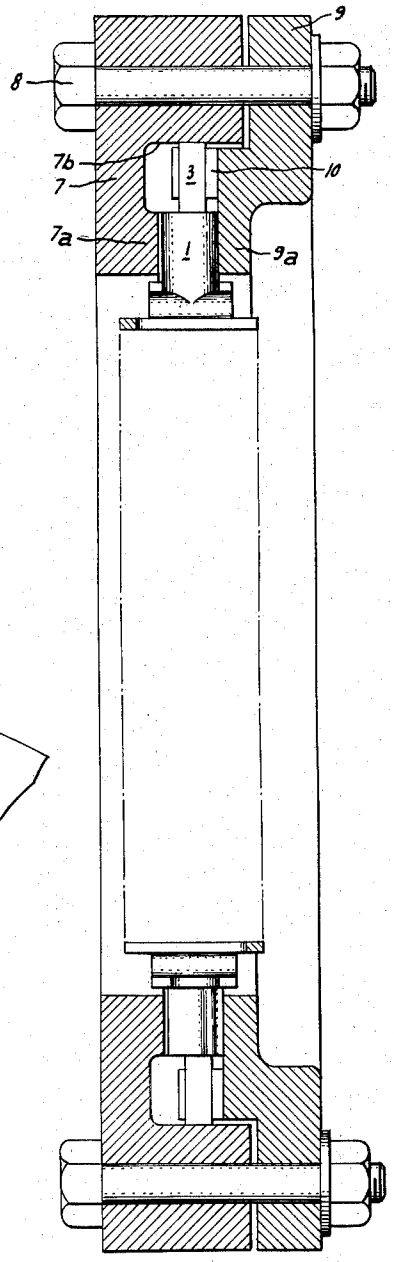
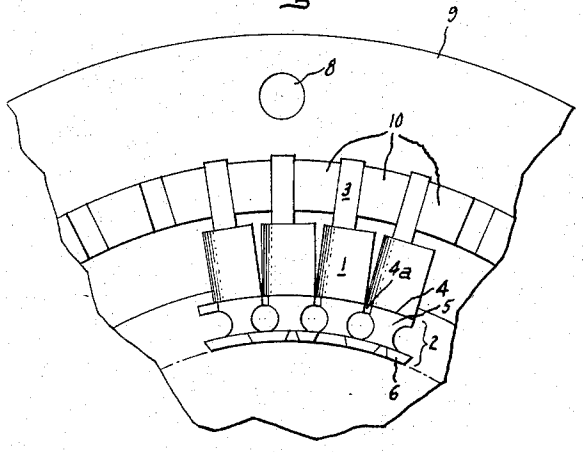


Fig. 3.



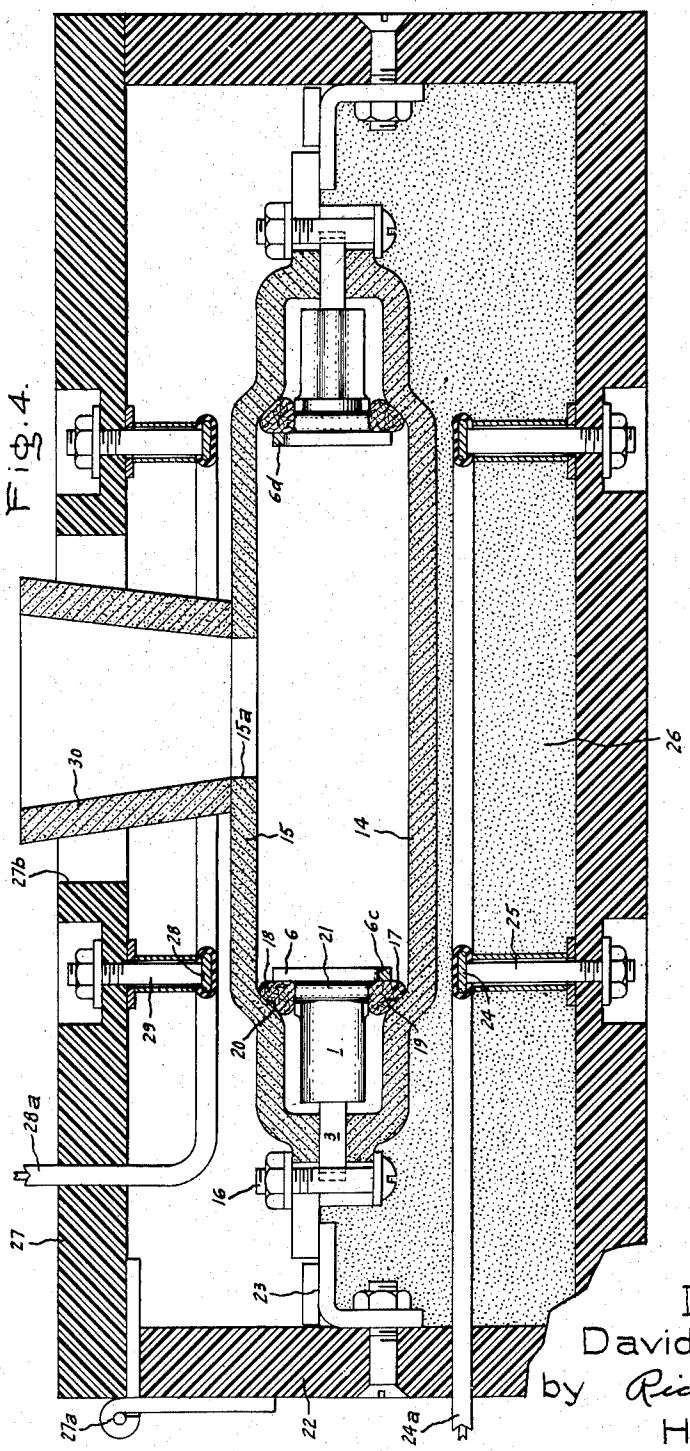
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TURBOMACHINE BUCKET-WHEEL FABRICATED BY CASTING

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Fig. 4.



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TURBOMACHINE BUCKET-WHEEL FABRICATED BY CASTING

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Fig. 5.

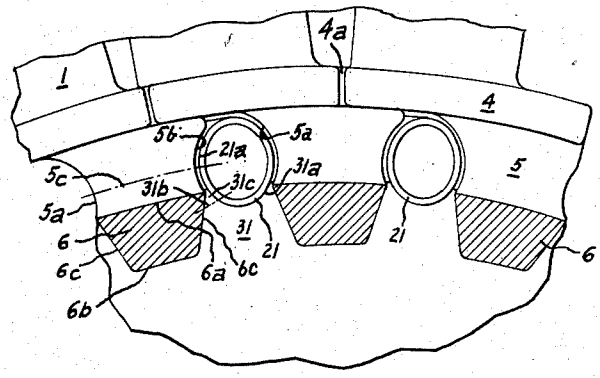
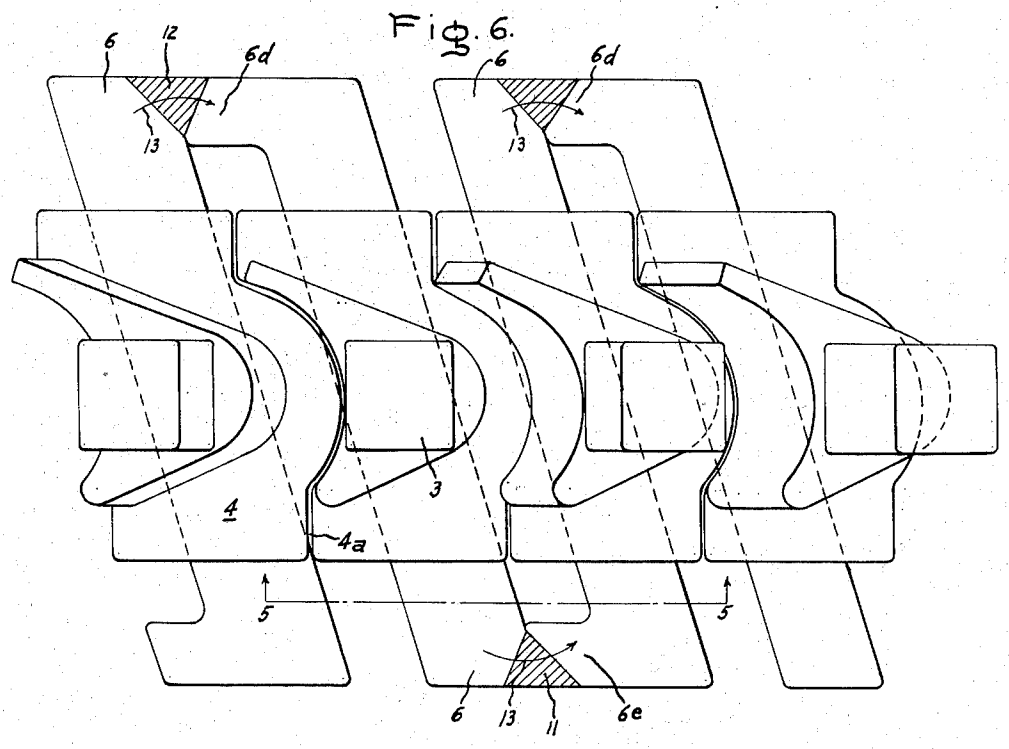


Fig. 6.



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2,894,318

TURBOMACHINE BUCKET-WHEEL FABRICATED BY CASTING

David J. Bloomberg, Newton, Mass., assignor to General Electric Company, a corporation of New York

Application October 8, 1952, Serial No. 313,734

8 Claims. (Cl. 29—156.8)

This invention relates to turbomachine bucket-wheels, particularly to improved method and apparatus for fabricating a bucket-wheel by casting processes.

Perhaps the simplest and cheapest way to make the rotor of an axial flow turbine or compressor would be to cast the circumferential row of blades or buckets integral with the disk member forming the web portion of the wheel. Heretofore this has not been feasible because of the extremely critical shape and dimension limitations to which the blades must be formed if the required aerodynamic performance is to be obtained. It is also important that the comparatively thin blades be inspected very carefully, as the normal operating stresses in them are so high that any smallest flaw would soon result in a more or less serious structural failure. Accordingly, it has been considered necessary to fabricate the blades or buckets separately, inspect them very carefully, retaining only those which are of the highest order of perfection, and then securing the separately fabricated blades to the rim of the wheel web.

An enormous variety of methods and structures have been devised for securing the blades to the wheel rim, most of them involving substanial mechanical complexity and requiring a high order of accuracy in machining the interfitting rim and bucket base portions. In comparatively recent years, it has at last been found feasible to weld the separately fabricated buckets to the rim of the web, as disclosed, for instance, in the United States patent to R. H. Thielemann, No. 2,454,580, issued November 23, 1948 and assigned to the same assignee as the present application. Because of the difficulty of getting satisfactory welds, it has been ordinarily considered feasible to use such a method only for turbine bucket-wheels of comparatively small diameter. While so welding the buckets has made a substantial improvement in the cost of small diameter bucket-wheels, the extreme care and high order of skill required in the welding operation has made it impossible to even approach the low cost of manufacture which might be expected if the entire rotor could be cast in one piece.

The object of the present invention is to provide an improved form of bucket-wheel fabrication which retains the advantages of fabricating the buckets separately, so they can be readily inspected and any with even the slightest defects rejected, while reducing still further the cost of fabrication by casting the wheel web portion and fusing the buckets thereto in the same operation.

A further object is to provide an improved turbomachine bucket-wheel specially designed so that the danger of interbucket cracking is reduced or eliminated.

A still further object is to provide a high temperature turbine bucket-wheel having buckets which may be cast individually or in groups of one high temperature resisting material which has little ductility and rather poor tensile strength, while forming the web portion of a different cast alloy having lower heat resistance but better strength characteristics.

Other objects and advantages will become apparent

from the following description taken in connection with the accompanying drawings, in which Fig. 1 is a perspective view of a single separately fabricated bucket, Fig. 2 is a sectional view of the welding fixture used in tack-welding a plurality of buckets to form the complete circumferential row, Fig. 3 is a partial top view of the welding fixture of Fig. 2 with the upper clamping ring removed, Fig. 4 is a sectional view of the ring of buckets assembled in the mold for casting the web portion, Fig. 5 is a detail view of a portion of the completed wheel rim, and Fig. 6 is a partial view in elevation of a portion of the completed wheel rim.

Generally stated, the invention is practiced by forming the individual buckets separately, as by precision-casting a suitable high temperature resisting alloy, tack-welding the separate buckets to form a complete circumferential row, assembling the ring of buckets in a mold shaped to define the wheel web portion, preheating the bucket bases to welding temperature, and casting the web so that the molten metal fuses with the preheated bucket bases.

Referring now more particularly to Fig. 1, taken in connection with Fig. 5, the separately cast bucket comprises generally a blade portion **1** and a base portion **2**. Formed integral with the outer end of the blade **1** is a radially projecting locating tang **3**. The bucket base portion **2** comprises a circumferentially and axially extending "platform" **4** adapted to cooperate with adjacent platforms to form a substantially continuous circumferential inner wall of the motive fluid flow path, an intermediate base portion **5**, and an inner "fusion tang" portion **6**. Attention is particularly directed to the fact that the intermediate base portion **5** has side portions defining concave transversely extending arcuate recesses **5***a*, **5***b*. The radially inner end portion **6** is adapted to be fused to the rim of the wheel web, and tapers inwardly from a maximum circumferential width at the imaginary plane **6***a* to a substantially smaller circumferential width at the extreme inner surface **6***b*.

While the separately formed buckets may be fabricated by any suitable method, such as extrusion, forging, machining from solid stock, etc., they are preferably formed by precision casting methods, such as that known as the "lost wax" process. The techniques for so casting separate buckets have reached a high order of development, so that buckets of the requisite perfection can be readily obtained. Before incorporating them in a bucket-wheel, each separately fabricated bucket is carefully inspected, as for instance by X-ray or other appropriate method, to make sure there is no slightest flaw. The ability to retain the advantages of thus separately fabricating and inspecting the individual buckets is an important feature of the present invention.

After the separate buckets have been finished and inspected, the next step is to secure them together to form a complete annular row. To this end, the welding fixture shown in Figs. 2 and 3 is employed. It will be readily seen in Fig. 2 that the fixture comprises a base ring member **7** having a plurality of circumferentially spaced clamping bolts **8** for securing a clamping ring member **9** so as to firmly hold the circumferential row of buckets in proper relation to one another. It will be seen in Fig. 2 that the base ring **7** has an annular portion **7***a* for engaging the blade portions of the buckets, the opposite sides of the blades being engaged by the radially inner portion **9***a* of the upper clamping ring. Engagement of the portions **7***a*, **9***a* with the blades insures that all will be positioned axially so as to lie in exactly the same plane. The engagement of the outer end surfaces of the locating tangs **3** with the inner circumferential wall surface **7***b* insures that the buckets will be properly positioned in a radial direction. Accurate circumferential spacing of the blades is insured by engagement of the

locating tangs 3 with a circumferential row of locating lugs 10 formed on the clamping ring member 9 in a manner which will be obvious from Figs. 2 and 3.

Thus, it will be apparent that the fixture of Figs. 2 and 3 securely supports the circumferential row of buckets in properly spaced relation to one another, much in the same manner as disclosed in Thielemann Patent 2,454,583. It is to be particularly noted that the base "platform" portions 4 define small circumferential clearance spaces with each other, as shown at 4*a*. Also, as may be seen better in the enlarged detail section of Fig. 5, the fusion tang portions 6 are circumferentially spaced so that the inter-tang space 31 is of substantially the same size and shape as the tangs themselves. It will also be noted that the arcuate recesses 5*a*, 5*b* cooperate with the corresponding recesses in the next adjacent buckets to define substantially circular recesses extending transversely of the wheel rim. A barrier member of ceramic or equivalent refractory material is disposed in each of these recesses. This may take the form of a ceramic rod or tube, as shown at 21.

With the buckets supported as in Figs. 2 and 3, each pair of adjacent bucket bases is secured together by a small tack weld, as shown more clearly in Fig. 6. It will now be observed that the bucket bases are not identical in all respects, alternate bucket bases having a circumferentially extending welding lug at one side of the wheel, as shown at 6*d*, while the other bases have a similar welding lug 6*e* at the opposite side of the wheel. As indicated in Fig. 6, the lug 6*e* is secured to the next adjacent base by the tack-weld 11, while the other set of lugs 6*d* are secured by the tack-welds 12. The importance of this alternating sequence of tack-welds is that it provides an electrical "grid," that is, a serpentine path of low electrical resistance through all the bucket fusion tangs in series, as indicated by the arrows 13 in Fig. 6. The importance of this will be seen hereinafter.

After tack-welding and cooling the buckets, the completed ring is removed from the welding fixture.

The method of casting the web portion of the wheel so that the bucket bases are fused to the web in the same operation is illustrated in the sectional view of the mold shown in Fig. 4.

While other methods for defining the shape of the cast web may be employed, it is preferred to use the so-called "shell-molding" process, in which a heated metal pattern is dipped into a mixture of molding sand and thermo-setting synthetic resin material, the heat from the mold causing a thin layer of the mixture to adhere to the surface thereof. The pattern is then raised from the sand-plastic mixture and baked in an oven until the plastic cures. The resulting comparatively thin shell is then stripped from the pattern. This shell-molding process is employed to form a lower shell mold portion 14 and an upper shell mold 15. As will be seen in Fig. 4, these shell mold halves cooperate to define the surface of the wheel web.

The outer circumferential portion of the shell molds are provided with recesses in which are disposed suitable clamping devices such as the bolts 16. Immediately adjacent the clamping bolts 16, the shell mold halves define recesses for receiving the locating tangs 3 of the respective buckets. It will be apparent that the clamping effect of the adjacent bolts 16 serves to grip the locating tangs 3 securely so that the buckets are positively located in circumferentially spaced relation to each other, so as to resist any tendency of the buckets to become displaced, either in a tangential or axial direction during the casting process.

It is also to be observed that the base portion of the buckets is engaged by a pair of somewhat yielding packing rings shown at 17, 18. While these rings may be of any suitable yieldable temperature-resisting material such as an asbestos composition, it is preferred to make them of glass fiber. It will be seen that each packing ring engages an inclined surface 19, 20 of the lower and upper mold portions, respectively. The inclination of these surfaces 19, 20 insures that the yieldable rings will be biased radially inward into contact with the fusion tang portion 6 of the base, also being held axially against the radial side surfaces of the intermediate bucket base portions 5.

Before assembling the upper packing ring 18 and the upper shell mold half 15, the ceramic barrier members 21 are inserted in each of the recesses defined by the adjacent arcuate grooves 5*a*, 5*b*. As shown in Fig. 5, the tubular ceramic member 21 need not fit the arcuate surfaces 5*a*, 5*b* exactly. A small clearance space, as shown at 21*a*, does no harm and makes assembly easier. These clearances may even do some good in facilitating egress of gases from the molten metal.

Returning now to Fig. 4, the mold is completed by assembling the upper packing ring 18 and the upper mold shell 15, and securing the clamping bolts 16. The mold is then supported in a flask comprising a box 22 made of some suitable non-magnetic material, such as asbestos board, provided with supporting ledges for the perimeter of the mold assembly. These may conveniently be in the form of bracket members 23 bolted to the side of the box 22.

In the bottom of the flask is supported an induction heating coil, which may be in the form of a single loop of a heavy conductor, shown at 24 as being secured to the upper ends of a plurality of spaced support posts 25. The lower half of the flask is filled with sand, as shown at 26, to conform to the shape of the lower shell mold and provide support for it during the casting operation.

The flask is completed by a cover member 27, which may be hinged at 27*a*. Secured to the cover is a second induction heating coil 28 supported on posts 29. The ends of the respective induction heating coils 24*a*, 28*a* project from the flask and are connected to a suitable high current, low voltage source of electrical energy, such as a welding generator. It will be observed that the heating coils 24, 28 are disposed in closely spaced relation to the welding tang portions 6 of the respective bucket bases.

The flask cover 27 defines a central opening 27*b* in which is disposed the pouring gate member 30, which communicates with a central opening 15*a* in the upper shell mold 15.

With the completed mold supported in the flask as shown in Fig. 4, it is necessary to preheat the fusion tangs of the buckets before casting the web portion. This is the function of the induction heating coils 24, 28. By passing a heavy current through these coils, strong eddy currents are induced in the serpentine electrical grid formed by the tack-welded fusion tang portions of the buckets. As will be apparent from a consideration of this serpentine path as illustrated in Fig. 6, these eddy currents will circulate through all the fusion tangs in series, so that each tang is subjected to a heating current of the same density as that occurring in the other tangs. Thus, all the tangs are uniformly heated. A further feature is that this heating current flows only through the tang portions 6. Because of the clearance spaces between the respective bucket portions 4, 5, there is little tendency for this current to stray into the portions of the bucket which are not to be heated. The result is that the tangs are brought very quickly to welding temperature, which may be on the order of 1700° F., while the other portions of the bucket are heated only by whatever heat is conducted from the fusion area. The insulating effect of the packing rings 17, 18, helps to reduce the transmission of heat by conduction from the fusion area into the blades. The ceramic barriers have the same effect; and from this standpoint it may be preferable to form the barriers as tubes, for the sake of the insulating air-space inside, rather than as solid ceramic rods.

With the fusion tangs of the buckets thus preheated, the mold is ready for pouring. Molten metal at a temperature of perhaps 2,300° F., varying with the type of metal used, is admitted through the pouring gate **30** and readily fills the space defined between the shell molds **14, 15.** With the gate disposed at the hub of the wheel as shown at Fig. 4, the molten metal has equal access to all portions of the web. As shown in Fig. 5, the space between adjacent fusion tangs **6** has a substantial taper outwardly, and this tapered configuration of the inter-tang space **31** gives the molten metal a better chance to feed into these spaces.

By comparison of Figs. 4 and 5, it will be apparent that the tangs **6** and the ceramic barriers **21,** taken in combination with the packing rings **17, 18** define a continuous circumferential barrier for the molten metal. In this connection, it is to be noted that the small clearance space **21***a* between the ceramic barriers and the bucket bases will not ordinarily permit the molten metal to enter to any appreciable extent, if this clearance is kept to a value below .01 inch. If there should be an excessive tendency for the metal to enter this clearance space, it can be readily cleaned out by running a reamer or small grinding wheel through these circular recesses between buckets after the wheel is removed from the mold. Ordinarily, this will not be necessary if the clearance space **21***a* is of the size stated.

After the mold is poured, it is permitted to cool for a few minutes. Then the flask may be opened and the shell mold removed for further cooling of the casting in air.

By reason of the above-described preheating of the fusion tangs, the molten metal readily fuses to the bucket bases as completely as if the bases had been welded to or cast integral with the wheel rim.

It is important to note the geometric configuration of the juncture between the bucket bases and the cast wheel rim, as shown in Fig. 5. By reason of the arcuate recesses **5***a*, **5***b*, the bucket base portion **5** has a minimum circumferential width at the plane identified by the dot-dash line **5***c*. This means that centrifugal stresses will tend to cause any stretching of the bucket at this plane rather than at the comparatively wider portion **6***a*.

It is particularly to be noted that the ceramic barrier **21** forms a concave surface **31***a* constituting the outer boundary of the cast wheel material **31.** This concavity is significant for the following reason. Experience with turbine bucket-wheels in which separately fabricated buckets are welded to a web has shown that perhaps the most important source of bucket-wheel failure has been small radial cracks which start where one bucket base abuts the next, these cracks growing progressively inward until the strength of the wheel rim is affected. The present bucket structure is carefully designed to resist the initiation of such inter-bucket cracking. It will be seen in Fig. 5 that the separately fabricated bucket bases do not abut each other directly but are separated by the substantial tapered mass of web material **31.** This web material fills the small triangular space defined between the ceramic barrier **21,** the fusion tang side surface **6***c*, and the imaginary plane identified **31***b* in Fig. 5. Centrifugal forces acting on the bucket will cause the base portion **5** to tend to pull away from this small triangular mass **31***c*, tending to form an incipient crack at the intersection of the side surface **6***c* with the web portion **31***c.* However, the concave configuration of the wheel web material **31** between the fusion tang **6** and the ceramic barrier **21** is such that stretching of the web material will occur, across the imaginary plane **31***b*, before the stresses occurring at the juncture of the web material **31***c* and the adjacent fusion tang material becomes sufficiently great to cause an incipient crack. Thus, the concave surface **31***a* serves to help make the wheel web material **31***c* of more nearly equal strength with the fused joint with the tang **6.** Actually, the fusion between the preheated tangs **6** and the web rim is so complete that the side "surfaces" of the tang **6***b*, **6***c* disappear into a homogeneous fused mass. The concave outer boundary surface **31***a* presents no discontinuities which might act as "stress-raisers" to cause inter-bucket cracking to begin.

Thus, it will be seen that the design of the bucket bases, the circumferential spacing between bases, and the cooperating ceramic barriers are carefully coordinated to produce a fused joint between bucket and wheel web which has maximum resistance to inter-bucket cracking. The clearances **4***a* between bucket bases provide room for free thermal expansion and contraction of the bases, without setting up thermal stresses between the bases and the wheel rim material.

After the web material has properly solidified and cooled, the shell mold is stripped from the bucket-wheel, the packing rings **17, 18** pulled off or machined off, and the finished outline of the web and bucket base portions obtained by suitable machining or grinding processes. Through use of the shell molding process to define the shape of the web, the cast wheel may conform very closely to the finished out line desired, so the only substantial amount of machining required is that necessary to remove the bucket locating tanks **3** and the projecting end portions of the fusion tanks **6,** so the side walls of the wheel rim are smooth.

Before or after machining, as desired, the ceramic barriers may be removed by mechanical means, as by driving them out with a suitable punch, or by chemical or other means. The resulting transverse passages may serve as cooling air passages, if so desired.

It will be seen that the invention provides a novel method of casting a bucket-wheel which retains the advantages of forming the buckets separately from the web so they can be properly inspected, while obtaining most of the advantages and economy of manufacture of the "all-cast" wheel.

While only one wheel structure and method of fabrication have been described specifically, it will be obvious to those skilled in the art that numerous alterations and substitutions of equivalents may be made. For instance, the ceramic barriers between bucket bases may be made of somewhat different configuration, and the transverse circular recesses between bases formed by running a suitable cutting tool through the wheel after the casting process. Also, other types of permanent or semi-permanent mold may be used to define the cast wheel web, instead of the "shell type" mold which at present seems most advantageous. The details of the flask and induction heating coil arrangement may obviously take many alternate forms.

It may also be noted that the annular resilient packing rings **17, 18** may be dispensed with and the shape of the shell mold modified so as to approach more closely the end surfaces of the fusion tank portions of the bucket bases. The clearance between the mold and the bucket bases would of course be made small enough that there would be no substantial tendency for the molten metal to enter. And arrangements for locating the buckets in the welding fixture could be used. For instance, the locating tangs **3** could be dispensed with and the annular portions **7***a*, **9***a* of the fixture suitably shaped so as to engage the curved surfaces of the blades. It will be obvious that any suitable mechanical means for fixing the location of the separate blades during the tack-welding operation could be employed.

Furthermore, improvements in precision casting technique may permit the complete ring of buckets to be cast in one piece, in which event any buckets found defective could be easily cut out and a sound replacement bucket welded in. In large scale manufacture, with perfected casting techniques, this modification would effect substantial savings.

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. The method of fabricating a turbomachine bucketwheel which includes the steps of separately forming and inspecting individual buckets each having a blade secured to a base adapted to extend generally parallel to the axis of the wheel with an arcuate recess in either side thereof disposed to cooperate with adjacent bucket bases to form a transverse circular recess between each pair of adjacent buckets, each base having also a tapered fusion tang portion disposed immediately adjacent and radially inward from said recess, alternate tangs having at one side of the wheel a circumferentially extending welding lug, the remaining tangs having such a welding lug at the other side of the wheel, assembling a circumferential row of buckets with said welding lugs substantially abutting the adjacent bucket base at the respective sides of the wheel in alternating sequence thereabout with the tangs in uniform circumferentially spaced relation, tack-welding each lug to the respective abutting base portion whereby a serpentine electrical path is provided through all bucket bases in series, assembling the tack-welded ring of buckets in a mold having a main pouring gate adjacent the center of the wheel and a circumferential portion at either side of the wheel spaced axially from the circumferential row of bucket bases with a non-metallic refractory barrier member of circular cross-section disposed in each of said circular recesses between adjacent buckets and with a heat-resistant packing ring disposed at each side of the wheel between said circumferential mold portions and the end surfaces of the fusion tangs and barrier members, whereby the mold defines the shape of the side faces of the wheel disk portion while said barriers and tangs cooperate to define a substantially closed perimeter for the wheel web, said mold having also annular induction heating coils disposed adjacent the respective sides of the annular fusion area formed by the tangs, preheating the bucket bases by passing a current through said coils until the fusion tangs reach substantially welding temperature, pouring molten metal through said gate to fill the mold whereby the molten metal fuses with the preheated fusion tangs, cooling the mold, removing the wheel from the mold, and extracting the barrier members from the interbucket recesses.

2. The method of fabricating a turbomachine bucketwheel which includes the steps of forming a ring of buckets each having a blade secured to a base, the base being adapted to extend generally parallel to the axis of the wheel with an arcuate recess in either side thereof disposed to cooperate with adjacent bucket bases to form a transverse substantially circular recess between each pair of adjacent buckets, each base having also a tapered fusion tang portion disposed immediately adjacent and radially inward from said recess, alternate tangs having at one side of the wheel a circumferentially extending lug, the other tangs having a similar lug at the opposite side of the wheel, said circumferentially extending lugs being integrally united with the fusion tang portion of the next adjacent bucket whereby a serpentine electrical path is provided through all tangs in series, assembling the ring of buckets in a mold having a main pouring gate adjacent the center of the wheel and a circumferential portion at either side of the wheel disposed closely adjacent the circumferential row of bucket bases, with a non-metallic refractory barrier member of substantially circular cross section disposed in each of said circular recesses between adjacent buckets, whereby the mold defines the shape of the side faces of the wheel disk portion while said barriers and fusion tangs cooperate to define a substantially closed perimeter for the wheel web, the mold having electrical heating means disposed immediately adjacent the respective sides of the annular fusion area defined by the tangs, preheating the bucket tangs by said heating means by causing an electric current to flow therethrough to substantially welding temperature, and pouring molten metal through said gate to fill the mold whereby the molten metal forms the wheel web with the rim thereof to the preheated fusion tangs.

3. The method of fabricating a turbomachine bucketwheel which includes the steps of separately forming a ring of buckets each having a blade secured to a base extending generally parallel to the axis of the wheel with an arcuate recess in either side of each base disposed to cooperate with adjacent bucket bases to form a transverse circular recess between each pair of adjacent buckets, each base having a tapered fusion tang portion disposed immediately adjacent and radially inward from said recess, the bucket bases being spaced circumferentially and separated by said recesses with each bucket having a projecting portion integrally united with the next adjacent bucket whereby an electrical path is provided through all fusion tangs, assembling the ring of buckets in a mold having a main pouring gate adjacent the center of the wheel and a circumferential portion at either side of the wheel and closely spaced from the respective end portions of the circumferential row of bucket bases, inserting a non-metallic refractory barrier member of generally circular cross section in each of said recesses between adjacent buckets whereby the mold defines the shape of the side faces of the wheel disk portion while said barriers and fusion tangs and the closely spaced adjacent portions of the mold cooperate to define a substantially closed perimeter for the wheel disk, preheating the fusion tangs by electrical heating means disposed in the mold closely adjacent the respective sides of the annular fusion area defined by said tangs to induce a flow of electric current therethrough until the tangs reach substantially welding temperature, and pouring molten metal through said gate to fill the mold whereby the molten web material fuses with the preheated bucket fusion tangs.

4. In a method of fabricating a turbomachine bucketwheel, the steps which include forming a plurality of separate buckets having base portions extending generally transverse of the wheel rim and including a fusion tang portion, assembling a plurality of said buckets to form a complete circumferential row with clearance spaces between each pair of adjacent buckets, securing each pair of adjacent buckets together at one side of the wheel only by means of a weld connecting the extreme end portions of adjacent fusion tangs to form an electrical path therebetween, said welded connections being at opposite sides of the wheel in alternating sequence around the circumference thereof whereby said fusion tangs and the welded interconnections therebetween constitute a serpentine electrical path, supporting said tack-welded circumferential row of buckets in a mold adapted to define the shape of the wheel web portion, induction-heating the fusion tang portions of the buckets by passing an electrical current through heating coils disposed at either side of the wheel so that induced heating currents traverse said serpentine electrical path, and pouring molten metal into the mold to form the wheel web, whereby the molten metal fuses with said preheated fusion tang portions of the bucket bases.

5. In a method of fabricating a turbomachine bucket wheel, the steps which include forming an integral ring of buckets each having a base portion extending generally transverse of the wheel rim and including a fusion tang portion, each pair of adjacent bucket bases being spaced apart circumferentially and connected by a circumferentially extending portion of narrow axial width completing a closed electrical path through all said fusion tangs, supporting said annular row of buckets in a mold defining the shape of the wheel web portion, the fusion tang portions of the buckets and the closely adja-

cent portions of the mold defining a substantially closed perimeter for the wheel web, preheating said fusion tang portions of the buckets by induction heating means disposed at either side of the wheel closely adjacent the annular fusion area occupied by the fusion tangs, and pouring molten metal into the mold to form the wheel web whereby the molten metal fuses with said preheated fusion tang portions of the bucket bases.

6. The method of fabricating a turbomachine bucket-wheel which includes the steps of forming a ring of buckets by connecting the base portions of adjacent buckets, assembling said ring of buckets in a mold defining the shape of a wheel web portion, preheating a fusion tang portion of said bucket bases by causing an electric current to flow therethrough, and pouring molten metal into the mold to form the wheel web whereby the molten metal fuses with said preheated fusion tang portions of the bucket bases.

7. An integral ring of turbomachine buckets adapted to be connected to a cast disk portion of a rotor, each of said buckets having a base portion extending generally parallel to the axis of the ring and including a fusion tang portion, adjacent buckets having welding lugs extending circumferentially in the same direction from alternate ends of said fusion tang and a weld between the welding lug of each bucket and a fusion tang of the adjacent bucket to form a closed serpentine electrical path in which heating currents may be induced for preheating said fusion tangs prior to casting said disk portion.

8. A ring of turbomachine buckets adopted to be connected to a cast disk portion of a rotor, each having a base portion extending generally transverse of the circumference of the ring and including a fusion tang portion, connecting means between the ends of said fusion tang portions of adjacent buckets, said connecting means being at opposite sides of the ring in alternating sequence around the circumference thereof to form a serpentine electrical circuit in which an electric current may be induced to preheat said fusion tang portions of said bucket bases prior to casting said disk portion.

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