

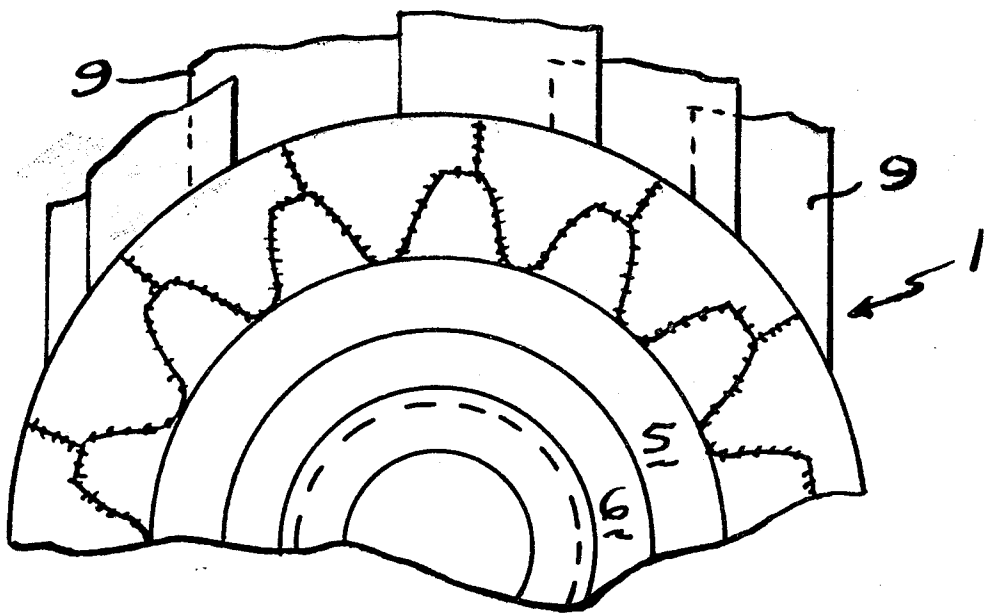
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[54] **TURBINE ASSEMBLY FABRICATION**
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B23p 15/02, B23p 15/04
[50] Field of Search..... 29/156.8 T,
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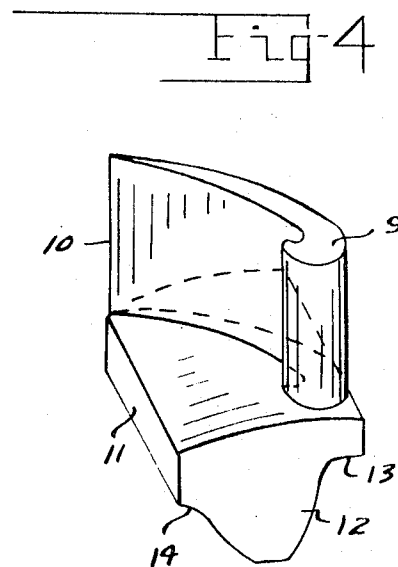
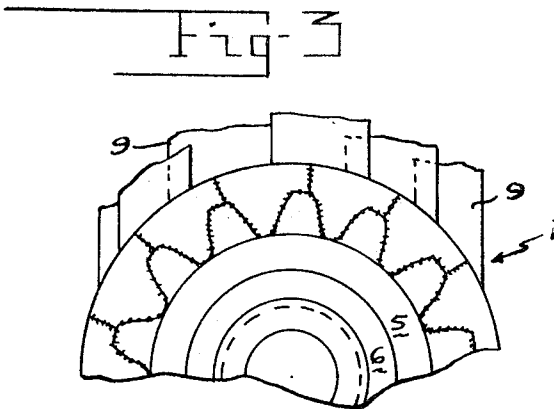
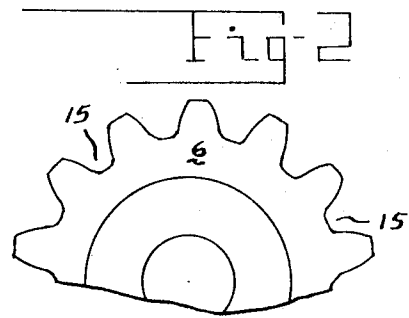
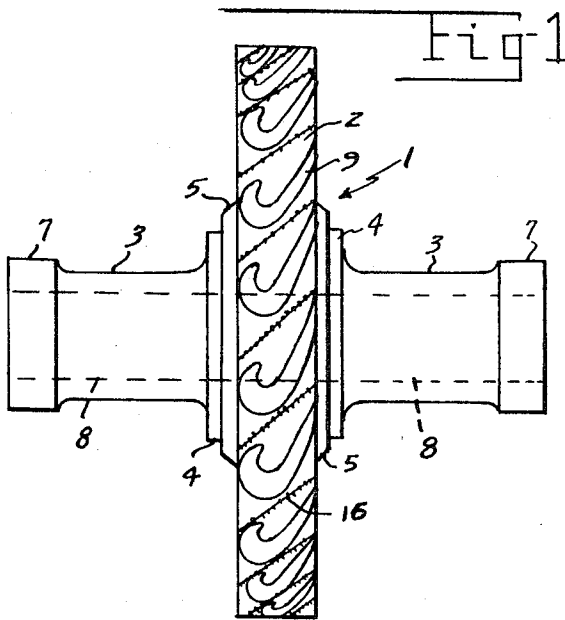
ABSTRACT: A small turbine for a jet engine is disclosed in which each bucket or blade is carried on a metal block which has a base portion conforming to a gear tooth shape. Slots in the hub of the turbine which receives the blade portion are cut on a gear cutting machine, this machine being indexed in a highly precisional manner. When the tooth-shaped portions of the blocks are assembled in the hub slots, the assembly is placed in an electron beam welder and the joints between the blocks and the hub, also between the abutting blocks are welded to form an integral structure.



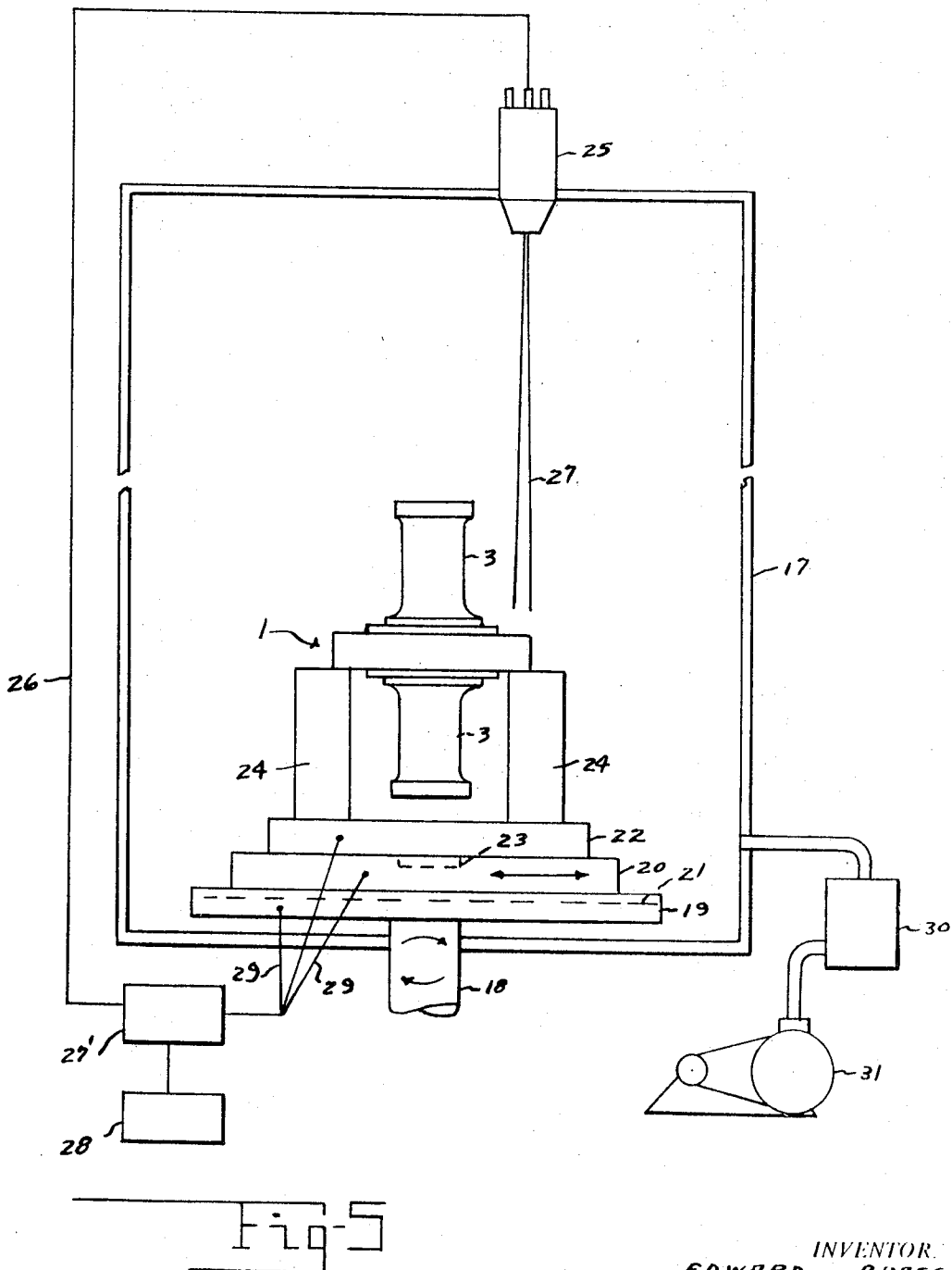
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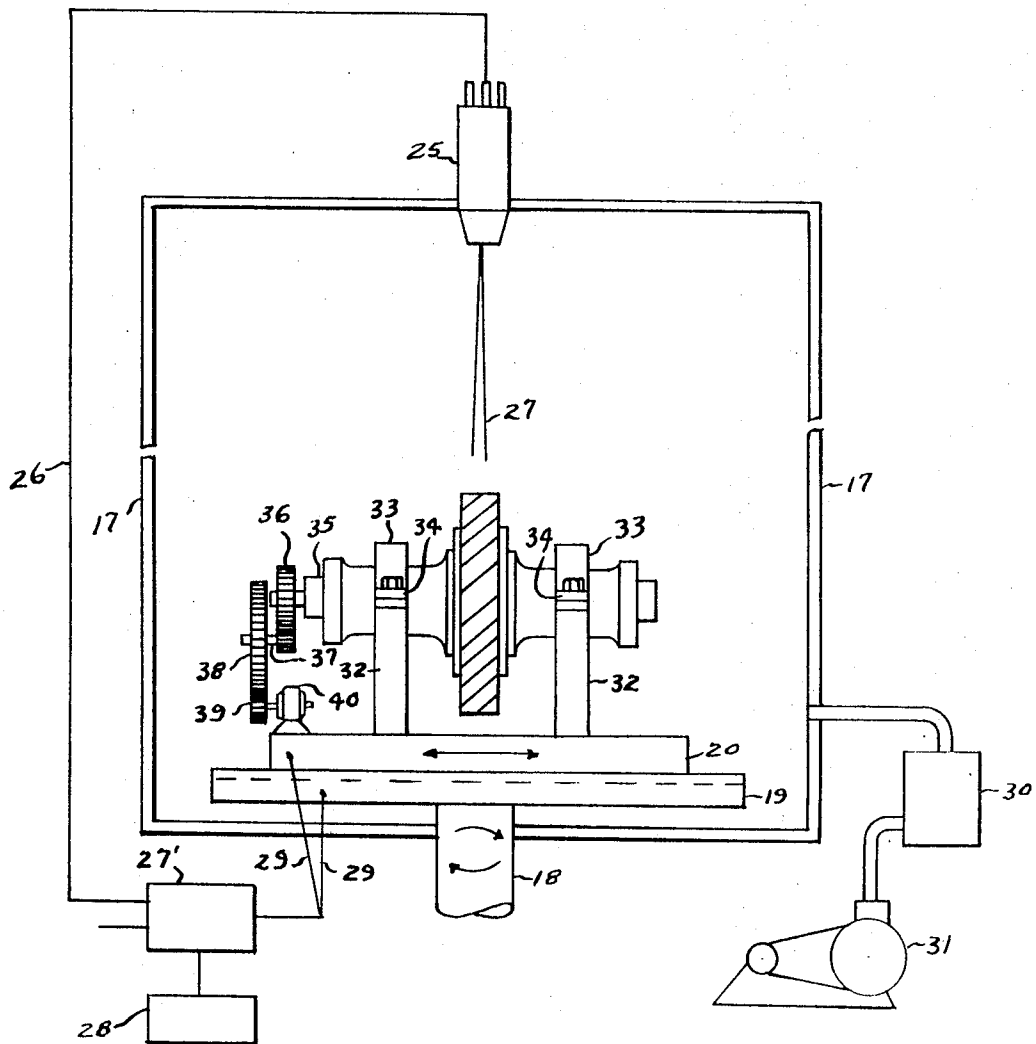


Fig. 6

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TURBINE ASSEMBLY FABRICATION

BACKGROUND OF THE INVENTION

The present invention relates to turbine wheels, used in connection with jet engines and more especially those of small size. A turbine wheel is mounted on the compressor shaft and gas flows at high velocity from the combustion chamber into a set of stationary blades that form the entrance to the turbine wheel. These stationary blades act as nozzles which serve further to accelerate the gases. To the rear of the stationary set of blades a set of rotating blades constituting a turbine wheel is presented to the gases as they leave the stationary nozzles. These blades are so designed so as to provide passageways which offer the minimum resistance to the moving gases and thus cause the turbine to rotate at a fast speed in order to turn the compressor. Since the latter provides air under pressure to the combustion chamber of the jet engine, it is essential in the interest of obtaining constant speed and continuous driving force at the jet that the gas passageways in the turbine be kept to a close tolerance depending on the shape of the blades and their size. Otherwise, irregularities in the turning effort at the compressor may occur and be reflected in the delivered thrust.

In the case of the compressors and their corresponding large turbines, greater tolerances as to size and shape of the space between blades are normal because any variation is proportionally less on account of the large amounts of gas being handled. It is sufficient to form the slots in the hub by a broaching machine, each slot having sides which taper inwardly and are grooved, so that the arrangement sometimes is referred to as a "Christmas Tree" shape. These grooves slidably receive protuberances on a block which carries the blade. An appropriately positioned pin is driven through the block to keep the blade from sliding out of position. The resulting distance between blades is obviously not to a close tolerance and would be completely unacceptable for turbines 2 inches to 4 inches outside diameter which handle very much less gas.

In the case of small turbines with their diminutive gas passageways, tolerances of any appreciable amount simply cannot be allowed, but instead, they demand absolute accuracy of dimension and shape which is most difficult to obtain.

In an attempt to obtain this accuracy of position and shape, it has been proposed to cut the entire wheel including the blades out of solid block material. But this procedure is expensive because the cutting tool must be carefully controlled, by computer or tape, in view of the intricate design of the blades.

In intermediate sizes, the turbine assemblies are sometimes cast in one piece, i.e., the blades are integral with the hub but quality is sacrificed in that the blading tolerances i.e., the blading profiles and interblade spacings, are higher than in the separate blade design. Integral turbine assemblies have also been fabricated by the well-known EDM (Electrical Discharge Machining) method. This method cuts the metal by a sparking or sputtering effect, using extremely high voltage. However, it has been found that the sputtering tends to create crack-propagating surfaces and also leaves these surfaces quite rough which would obviously reduce the streamline effect. Moreover, the sputtering electrode changes its shape during operation which further adds to the irregularity of the cut. If this method were used for the small size turbines, i.e., of the order of 2 to 4 inches in diameter, it is impossible to obtain the extremely close tolerance profiles are necessary.

SUMMARY OF THE INVENTION

An object of the invention is to provide an improved and practical method of making small turbine wheels for jet engines.

Another object is to provide a turbine wheel, particularly of small size and in which the blades or buckets are tightly secured to the periphery of the wheel.

Still another object is to provide a small turbine in which the blades are of complicated design and either with the interblade spacing must conform to extremely close tolerance.

A further object is to provide a relatively small turbine of the kind mentioned and in which the manufacturing costs are relatively low, notwithstanding the high precisional requirements.

These objects are obtained, in brief, by cutting slots of a gear tooth shape in a hub by a precise gear cutting and indexing machine, and providing a gear shape tooth on the base of the blade. Thereafter, the base portion is fitted into the slot of the wheel and the entire assembly is then welded by an electron beam, i.e., cathode-ray effect, to form an integral unit.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 represents a plan view of the improved turbine wheel.

FIG. 2 is a fragmentary end view of the hub portion of the wheel and showing the gear tooth slots, ready to receive the blade blocks.

FIG. 3 illustrates a partial end view of the turbine shown in FIG. 1 but with the blades broken away.

FIG. 4 is a perspective view, on a larger scale than in FIGS. 1 and 3, of a blade block.

FIG. 5 shows by way of diagram, a typical apparatus which may be employed for making some of the welds in securing the blades to the hub of the turbine wheel.

FIG. 6 illustrates, also by diagram, similar apparatus for making the remaining welds on the wheel to complete the entire turbine unit.

Referring more particularly to FIGS. 1 and 3, reference character 1 generally designates a relatively small turbine wheel having centrally positioned vane or bucket portion 2. There is a pair of outwardly directed sleeve portions 3 which are provided at their inner ends with flange 4 for securement to a flange 5 of the hub portion 6, (FIG. 2), as by welding. The sleeves 3 are provided with flanges 7 at their outer ends. An axial bore 8 passes through the turbine wheel for mounting the latter on a compressor shaft (not shown) of a jet engine.

The turbine has a number of blades or buckets 9 of which an outline of each is shown in FIG. 1, and these blades are equally spaced about the hub portion 6. An enlarged perspective view of the blade is shown in FIG. 4. The blade is supporting number is cut to shape, preferably from a solid block of metal by any appropriate machine such as a milling or shaping machine in any suitable well-known manner. The blade is of the well-known convolute shape having a predetermined depth as indicated 10. The blades when assembled on the turbine wheel are adapted to receive gases delivered by the stationary ring of nozzles (not shown) to provide a strong and continuous rotary effort on the compressor shaft. This shaft carries a compressor (not shown) which provides air under high pressure to a combustion chamber and the latter furnishes the gases which rotate the turbine and produces a jetlike stream of gas for propulsion purposes. The sides 11 of the block are parallel to one another and extend obliquely, as seen in FIG. 1 and in the particular case shown at about 45° with respect to the front and rear faces of the block in order to accommodate the angular setting of the blade. These sides are of substantial thickness and from the lower portions thereof there extends downwardly a toothlike projection 12 (FIG. 4), similarly to the shape of a gear tooth and is of precisely the same shape and size as the gear tooth recesses are formed in the hub of the wheel as will be explained hereinafter. As seen in FIG. 4, the toothlike projection 12 is not centrally located with respect to the side portions 11 but slightly to the left of the centerline between these two sides. Thus, there is a fairly wide flat surface 13 between the right-hand side of the root of the tooth 12 and the right-hand sidewall. The left-hand side of the tooth terminates in a narrow curvilinear portion 14. The purpose of these particular shapes at the root of the toothlike extension or base will be made clear when the blocks are ar-

ranged within recesses cut into the hub as will be explained hereinafter.

As shown in FIG. 2, the hub 6 is placed on a gear cutting machine, which, as is well known in the art, can be furnished with a high precisional cutting tool and indexing device. Slots 5 (FIG. 2) are cut into the hub in an oblique direction corresponding to the angle of the sides 11 of the blocks these slots are shaped to conform precisely to the shape of the tooth 12. The slots are equidistantly spaced about the hub of the wheel, the number of which will depend on the number of blades that are to be employed around the periphery of the turbine. In view of the precisional manner in which a gear cutting machine operates, including its indexing feature, the slots 15 can be cut to an extremely close tolerance both as to shape and spacing, similar to a high precisional gear. Assuming that the blocks carrying the blades are similarly cut accurately to size, the insertion of the tooth 12 in its corresponding slot of the wheel will cause the sides of the block closely to abut the adjacent block around the wheel. This close abutting effect as between the blocks is indicated by the diagonal lines 16 in FIG. 1. It will be noted that the abutting line between the right-hand side 11 (FIG. 4) of the block is slightly to the right of the centerline of the toothlike recess 10 over which it extends on account of the wider area found at the surface 13 than at the surface 14. It will be noted that due to the shape of the toothlike extension 12 and the parallel sides 11 of the block, the latter can either be slid into position from the side of the hub or can actually be pushed downwardly toward the circumference of the hub in order to assemble the blades in position. If desired, the sides 11 can be given a slight "tow" inwardly to assure a still tighter fit between blocks.

The next step is to join the various parts into an integral unit. I have discovered and in accordance with another aspect of my invention that instead of employing ordinary forms of welding, such as the electrical discharge machine method, the design of having the various blocks abut one another closely about the periphery of the wheel and held within toothlike recesses in the hub lends itself peculiarly well to the electron beam welding method which will now be described. In FIG. 5, there is shown a typical machine of this type and includes a large rectangular compartment 17 hermetically sealed, and evacuated to a very high degree. The lower part or bottom of the compartment has a sealed opening for receiving a shaft 18 connected to motor (not shown). This shaft extends into the compartment and carries a circular table 19 which has a fairly deep and wide slot running transversely over the face of the table. On top of the table there is a circular plate 20 of metal provided with a tongue which is adapted to slide within the groove 21 formed in the table. The plate 20 carries a smaller plate 22 having a tongue 23 which is adapted to slide in a groove formed at the top of the plate 20. The plate 22 is provided with a pair of heavy thick uprights 24 of metal secured in any suitable manner to the plate 22 and forming a support at two diametral positions along the lower side surface of the wheel 1 so as to permit one of the sleeve extensions 3 to extend downwardly between the two uprights. The wheel may be secured to the upper surface of the uprights 24 in any suitable well known manner. There are several mechanical controls in the form of connecting rods, gear trans, gear-rack mechanism and etc., which can move the plate 22 to any desired distance and in any direction toward and away from the reader along the slot 23, also to cause the plate 20 to move in a direction at right angles to the movement of the plate 22 and along the slot 21. These controls, also control of the direction of rotation of the table 19 through its motor (not shown) can be exercised with precision in any suitable and well-known manner from positions exterior of the compartment. Thus, the turbine wheel positioned on the uprights 24 can be moved universally in any horizontal direction due the movement of the plates 22, 20 and the rotary plate 19, but not in the vertical direction. The top portion or upper cover of the compartment 17 has a sealed opening for receiving a powerful cathode-ray gun 25 with suitable electrical conductors diagrammatically indicated

at 26 for the purpose of producing intense cathode rays 27 which will impinge on the various joints formed between the blade blocks and the hub of the wheel. These conductors pass into control unit 27' supplied with electrical energy from a source 28. The control apparatus 27' houses the control panel including the various electromagnets, switches, safety devices rheostats, etc., which are connected to the various mechanical actuating devices (not shown) for the plates 22 and 20, also for rotating plate 19. That the control of these elements rests in the control unit 27' is diagrammatically indicated by the leader lines 29. All of these devices are well known in the art, also the manner in which they control the operating parts within the compartment 26 for moving the turbine wheel very slowly in any direction in the horizontal plane. There is shown a diffusion pump 30 and a mechanical pump 31 for providing the high degree of vacuum necessary within the compartment when using the cathode-ray gun 25. This apparatus needs no further explanation as it is also well known in the art for providing high vacuum. It is apparent that with careful manipulation of high control apparatus 27', the various plates 22, 20 and 19 can be moved in diminutive amounts along any and all of the side joints between the blocks adjacent one another and also between each block the abutting surface of each block and the abutting surface of the wheel hub. This side welding effect is shown by the short cross or transverse lines (indicated as stitches) in FIG. 3. After one side of the wheel has been welded, the other side is then exposed to the cathode rays so that the weld can be formed along both sides of the wheel. This weld penetrates the joints to any suitable depth may be desired depending upon the type of welding duration, and also the intensity of the cathode rays 27.

In order to weld the circumferential joint areas of the wheel, a mechanical setup such as shown in FIG. 6 may be employed. In is figure, like pieces of apparatus similar to those shown in FIG. 5 have been given the same reference characters. The plate 22 and the uprights 24 are dispensed with so that there is used at this time the rotary table 19 and the traversing plate 20. The latter is provided with a pair of uprights 32 terminating in the lower part of a bearing which fits around the under surface of the sleeves 3 of the wheel. The bearing or journal is completed by a semicircular member 33 which is provided with extensions 34 for bolting to similar extensions on the lower part of the bearing. The bearing is such as to permit the sleeve portions 3 to rotate freely and yet be held rigidly in position above the plate 20. A shaft 35 extends through the wheel and at its reduced end carries a gear 36 which meshes with a smaller gear 37. The latter is supported on a shaft 37 which also carries a large gear 38. Gear 38 meshes with a small gear 39 mounted the shaft of motor 40. Thus, as the motor is energized from the control panel in any suitable well-known manner, the array of gears provides a considerable reduction in the speed of the shaft 35. Control is also exercised of the transverse movement of the plate 20 and the rotary movement of the table 19, when necessary.

Thus, as in the case of the FIG. 5, the cathode rays 27, which are stationary in space, can be caused to impinge on any part of the circumferential area of the wheel by proper control at the panel 27' and can weld the peripheral portions of the abutting surfaces between the blocks 1 as indicated by the "stitching marks" in FIG. 1. The depth of the weld can be readily determined or controlled by the speed with which the surface being welded is moved past the point of impingement of the cathode rays and also by the intensity of the rays. The latter is a function of the voltage applied to the gun. It is therefore evident that the abutting surfaces of the parts, both down the sides of the wheel and also along the periphery can be firmly welded to each other by the cathode rays so the parts including the blades mounted on the blocks constitute an integral structure. It has been found that cathode-ray welding, particularly in the case of turbine wheels of small diameter, leaves the surface quite smooth, notwithstanding the firmness of the weld and there are no concavities from which cracks or other imperfections of the surface can occur. It is further

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evident that the welding process, both along the sides of the wheel and also around the circumference can be done automatically at the control apparatus 27' so that the turbine wheels are in finished form immediately after the welding operation and conform precisely to uniform dimensions and spacing between the blades. By cutting the slots or grooves 15 in the hub on a precision indexing gear cutting machine of any suitable and well-known type, the peripheral position of the blades i.e. the spacing is absolutely assured provided that there is a close fit between the tooth-shaped extension 12 on each block and the similarly shaped slot or groove in the wheel hub.

I claim:

1. In the art of fabricating a turbine wheel, the step of cutting equidistantly spaced slots about the hub of the wheel, 15

said slots being cut to gear tooth configuration by a precisional gear cutting machine, the further step of cutting blocks of metal having a lower portion of the same form as a gear tooth of precisely the same shape and size as said slots, and upper portion formed as a blade of the turbine, the further step of inserting the lower portion of the respective blocks in the slots so that the sides of the block abut one another and securing the abutting surfaces of the blocks and the abutting surfaces of the hub and the lower portions of the block together to complete the fabrication of the turbine wheel.

2. The method of fabricating a turbine wheel according to claim 1 and in which the securing step is accomplished by the use of electron beam welding.

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