March 3, 1964 J. L. LAZAR ETAL 3,122,823

TURBINE WHEEL AND METHOD OF MAKING SAME

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Fig. 2

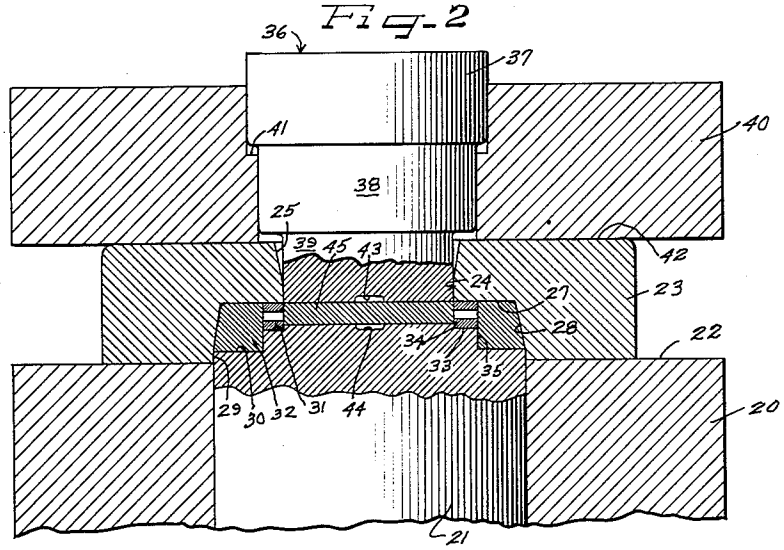

Fig. 3

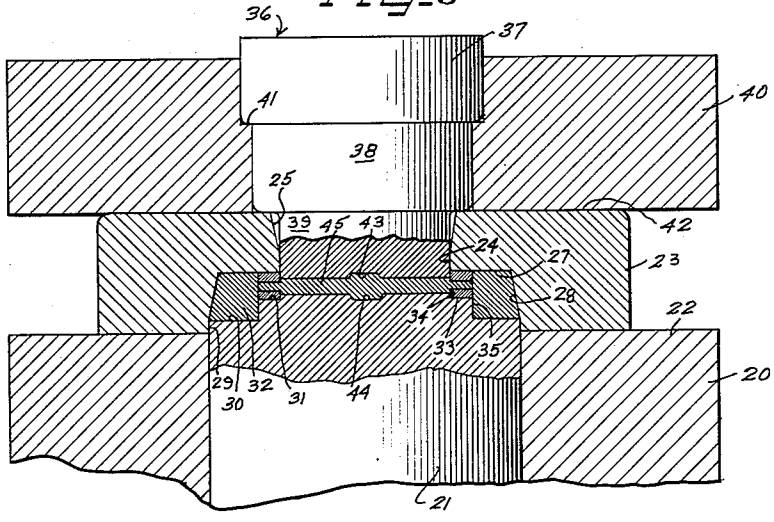

Fig. 1

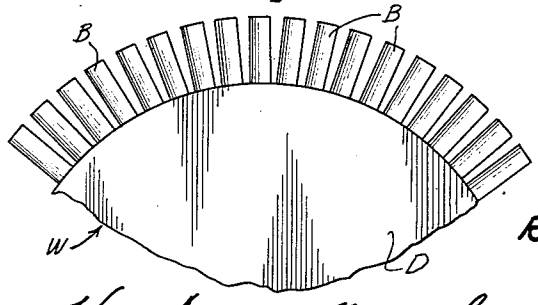

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Fig-4

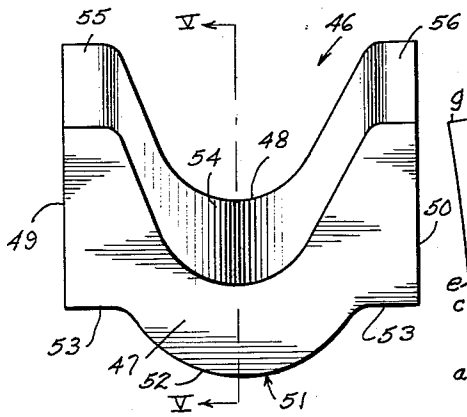


Fig-5

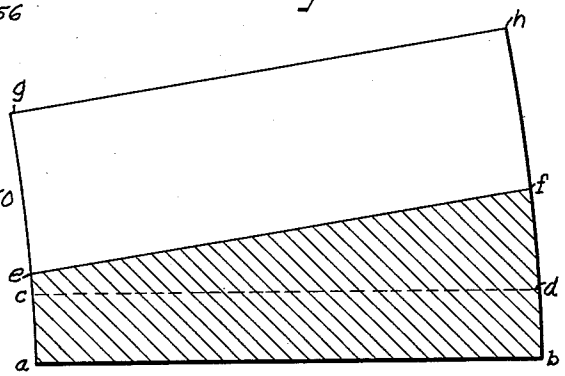


Fig-6

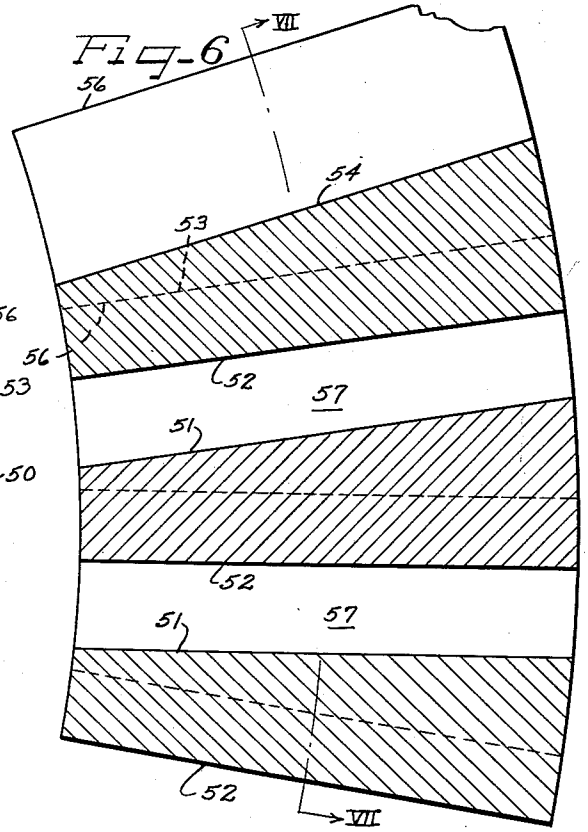
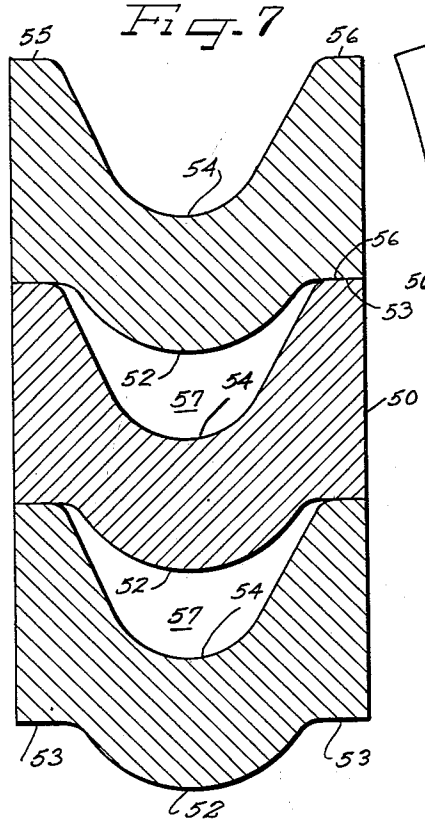


Fig-7



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TURBINE WHEEL AND METHOD OF MAKING SAME

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Fig-8

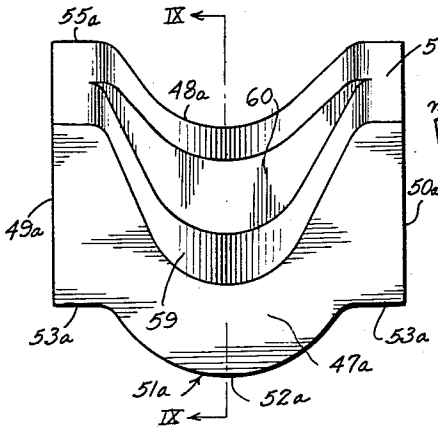


Fig-9

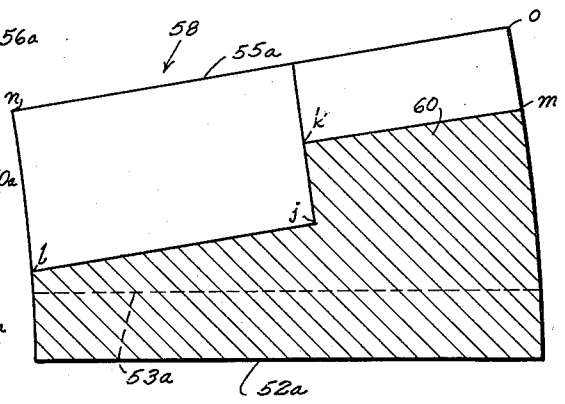


Fig-10

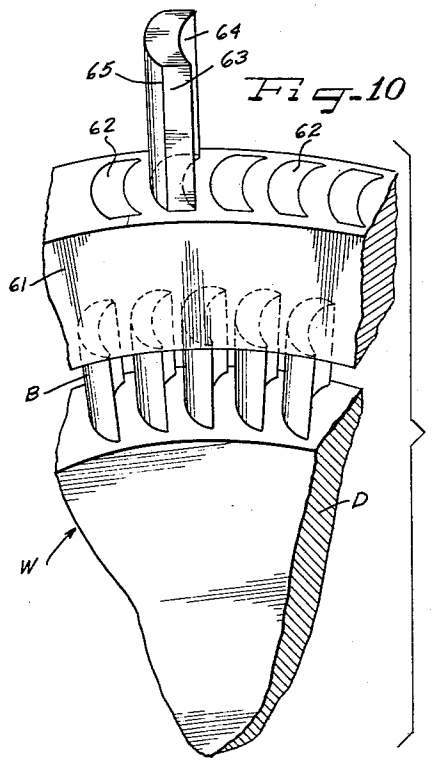
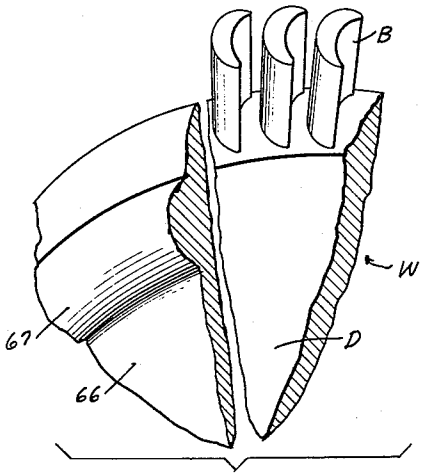


Fig-11



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TURBINE WHEEL AND METHOD OF MAKING SAME

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Fig-12

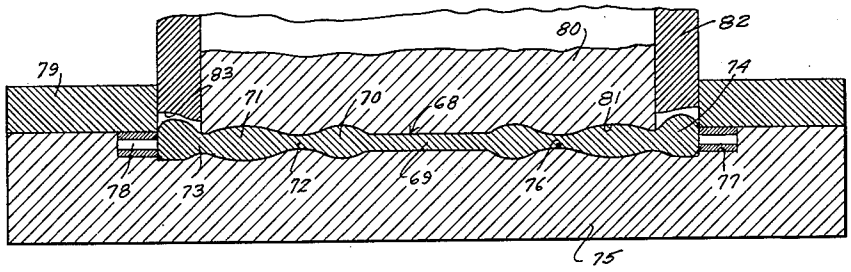


Fig-13

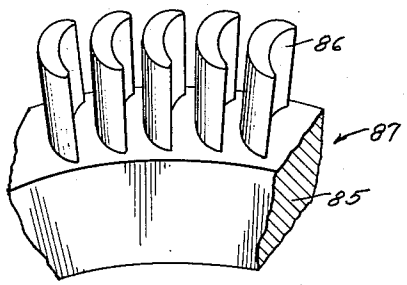
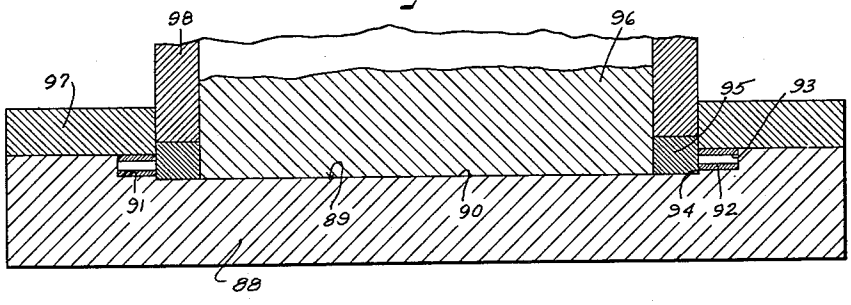


Fig-14



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3,122,823

TURBINE WHEEL AND METHOD OF MAKING SAME

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Filed Apr. 22, 1959, Ser. No. 808,128
8 Claims. (Cl. 29—156.8)

The present invention is concerned generally with the manufacture of turbine wheels and related articles, and is more particularly concerned with the formation of rotors and the like for turbines, compressors and related applications, featuring the forging of rotor blades from a metal mass which additionally provides a blade supporting structure in the form of a disc or rim portion.

Present techniques of making turbine wheels generally requires either broaching or casting, and in either of those methods it has been found difficult to maintain the proper dimensioning between the blade airfoils and roots. Accordingly, each of these methods have substantial time and cost limitations, and one solution proposed has been to precision cast or forge turbine blades and to seal the airfoil sections in a ring made of a material such as Kirksite metal. The assembled ring is placed in a holding cavity in a pressed die and held by an upper die member. A hot billet is then placed in the center of the ring and by the application of forging pressures, the billet is extruded under and around the blade roots. While the described method has the advantage of requiring only minor machining to remove excess metal from the wheel face, it is immediately apparent that this process is at least a two-step method and still leaves much room for improvement from time and cost standpoints.

It is accordingly an important aim of the present invention to provide a method of making turbine wheels and like articles wherein a blank is subjected to forging conditions to form therefrom a plurality of circumferentially spaced turbine blades integral with the remaining metal mass of the blank which provides the supporting structure for said blades.

Another object of the invention lies in the provision of a turbine wheel in which the blades and disc or rim structure supporting the same are an integral and unitary forged body originating from the same metal mass.

A further object of the present invention is to provide a method of forming turbine wheels and the like, which comprises supporting a plurality of blade shaping members in circumferentially spaced relation, locating a metal body of sufficient mass to provide the blades and supporting structure therefor radially inwardly of the blade supporting members, and applying forging pressures to the metal body to move the same radially outwardly between the blade shaping members to form the blades and to provide a remaining metal mass integral therewith forming the supporting structure for said blades.

A still further object of the invention lies in the provision of a forged turbine wheel and the like, comprising a plurality of circumferentially spaced turbine blades, and a supporting member for said blades and integral therewith, said member and blades being of the same metal composition and being both formed from the same original metal blank, whereby grain lines in the blades are continuous with grain lines in the supporting member therefor.

An even further object of this invention is to provide apparatus for forming turbine wheels and the like from a unitary metal mass to provide turbine blades integral with a supporting member therefor, comprising a female die member having an annular recess therein, a plurality of blade shaping members supported in said recess in circumferentially spaced relation therealong, said shaping

member radially inwardly thereof defining a space for locating a metal blank against the die member, and a male die member movable relative to the female die member to apply forging pressures against the blank to move the same radially outwardly between the blade shaping members to form the turbine blades and to provide a remaining metal mass integral with the blades and forming the supporting structure therefor.

Other objects and advantages of the invention will become more apparent during the course of the following description, particularly when taken in connection with the accompanying drawings.

In the drawings, wherein like numerals designate like parts throughout the same:

FIGURE 1 is a fragmentary elevational view of a turbine wheel formed in accordance with the principles of this invention;

FIGURE 2 is a side elevational view, with parts broken away and with parts in section, showing a metal blank in an exemplary forging apparatus prior to formation of the turbine wheel;

FIGURE 3 is a view similar to FIGURE 2, showing the apparatus with formed turbine wheel therein;

FIGURE 4 is an elevational view of one form of blade shaping or insert member;

FIGURE 5 is a sectional view taken substantially along the line V—V of FIGURE 4;

FIGURE 6 is a view similar to FIGURE 5 and showing a plurality of insert members abutting one another as when used in the apparatus of FIGURES 2 and 3;

FIGURE 7 is a sectional view taken substantially along the line VII—VII of FIGURE 6;

FIGURE 8 is an elevational view of another form of insert member and provided with a stop therein;

FIGURE 9 is a sectional view taken substantially along the line IX—IX of FIGURE 8;

FIGURE 10 is an exploded and somewhat diagrammatic view to illustrate a blade shaping structure of ring configuration and showing in fragmentary form a turbine wheel as produced therefrom;

FIGURE 11 is a fragmentary elevational view showing in part another form of blank which may be employed and in part the turbine wheel formed therefrom;

FIGURE 12 is a side elevational view, with parts broken away and with parts in section, illustrating exemplary apparatus which may be used to form the wheel structure of FIGURE 11;

FIGURE 13 is a fragmentary side elevational view of a turbine wheel produced by the present invention and in which the supporting member is of annular shape;

FIGURE 14 is a side elevational view of suitable apparatus to produce the wheel of FIGURE 13, portions of the apparatus in this view being broken away and other parts being shown in section.

Briefly stated, a rotor or wheel for turbine and compressor applications is produced by the present invention by utilizing a blank of either pancake or ring configuration, and if desired, when utilizing a pancake blank, thickened portions may originally be formed thereon to provide sufficient metal mass for the extruded turbine blades. Cooperating male and female die members are illustrative of the forming means employed, and in such apparatus the female die member is provided with an annular recess in which is seated either an insert ring providing the blade shaping members or said members may take the form of a plurality of abutting individual inserts defining therebetween the blade shaping cavities. The cavities are closed at the ends providing the turbine blade tips, and the stop at the end of each cavity may be either the female die member or an annular ring seated therein. Suitable die structure is provided to retain the insert members or insert ring in the recess in the female die. The metal blank,

whether it be of pancake or ring configuration, is seated against the female die member radially inwardly of the insert or blade shaping members, and by imparting relative movement between the male and female die members, the metal blank is moved or forced radially outwardly into the blade shaping cavities to form the turbine blades and to produce a remaining metal mass of reduced thickness as compared with the original thickness of the blank, this remaining mass providing the supporting structure for the blades. As was mentioned, the supporting structure may be either a solid disc, or a ring member to which a hub may be subsequently secured. Other features of the structure and method of this invention will become apparent as the description now proceeds.

Referring now to the drawing and first to FIGURE 1 thereof, a turbine wheel generally designated as W comprises a disc D integral with and supporting a plurality of circumferentially spaced blades B of airfoil shape. The disc D in the illustrative showing of the FIGURE 1 is a solid metal mass, although as will be specifically described hereinafter, the supporting structure for the blades B may be a ring or rim to which a hub of a different metal is secured for particular applications. The blades B of FIGURE 1 are arcuate in shape and each is of constant thickness from the tip to the base thereof, however, variations can readily be practiced in the method herein disclosed to produce tapered shapes and blade structures of different contours or configurations. The metal forming the turbine wheel W may be those customarily employed for turbine compressor rotor applications, and stainless steel, titanium and the like provide the desired results in the practice of the present invention.

A first form of exemplary apparatus to practice the present method and to produce the turbine wheel W of FIGURE 1 is shown in FIGURES 2 and 3. Upon reference thereto, it will be seen that there is provided a supporting base **20** which receives a female die member **21**, the supporting base having an essentially flat surface **22** supporting and securing an apertured annular die holder **23**. The die holder **23** has a bore **24** extending therethrough and comprising a tapered mouth portion **25** and a reduced diameter throat portion **26** which connects with a relatively flat portion **27** and tapered portion **28** which terminates in a relatively short length straight wall portion **29**.

The female die member **21** is provided with a pair of adjacent annular recesses or grooves **30** and **31**, and seated in the recess **30** is a retaining ring **32** which may take the form of three separable abutting parts. The recess **31**, on the other hand, seats blade shaping means generally designated as **33**, the structural features of which will be specifically described later. It will be seen from FIGURE 2 that the blade shaping means seats in the annular recess **31** and is restrained against radial inward movement by a shoulder **34** in the upper surface of the die member **21**. Further, it may be observed that both the retaining ring **32** and the blade shaping means **33** are held in position by the die holder **23** and that the retaining ring abuts against a shoulder **35** formed in the upper surface of the die member **21**. The retaining ring **32** in the embodiment of FIGURES 2 and 3 provides a stop for metal flow during formation of the turbine blades in the blade shaping means **33**.

Cooperating with the female die member **21** is a punch or male die member **36** having stepped portions **37** and **38** and an active end portion **39**. The punch **36** is movable relative to a punch holder **40**, which may be seen to be bored to provide a shoulder **41** limiting travel of the punch **36**, and it will be seen that the punch **36** is further limited in its axial travel by contact of the stepped punch portion **38** against relatively flat upper surface **42** of the die holder **23**. The active end **39** of the male die member **36** is guided during axial travel by the tapered mouth portion **25** of the die holder **23**, and the lower face of the punch active end **39** has a recess **43** formed generally centrally therein which cooperates with a corresponding recess **44** in the female die member **21** to provide a hub or embossment on metal blank **45** during forging in the apparatus of FIGURES 2 and 3. Provision of a hub is a matter of choice, however, and the strength requirements of the turbine wheel W may in particular applications render such a central thickened portion unnecessary.

Metal blank **45** in FIGURE 2 is shown to be of generally circular pancake configuration having a generally constant thickness throughout. As explained hereinafter, other blank configurations are within the contemplation of this invention, and a solid blank may have annular thickened portions at various sections thereof and the metal blank may also be of ring shape.

Relative movement of the punch member **36** with respect to the stationary die **21** and the exertion of forging pressures by said punch upon the blank **45** bottomed against the die **21** compresses the blank **45** and flows the metal mass radially outwardly into the blade shaping means **33** to form the turbine blades in the shaping cavities provided by the blade forming means **33**. The structural details of one form of blade shaping means are shown in FIGURES 4 to 7, to which reference is now made. While individual inserts or blade shaping members are shown therein, it will later be seen that a continuous ring is also productive of the desired results.

Each insert or blade shaping member **46** is contoured or machined to generally a U-shape configuration, and is thus formed to produce, when assembled with other insert members, turbine blades of constant thickness throughout the axial length thereof. Each member **46** comprises generally flat and parallel side surfaces **47** and **48**, generally flat and parallel end surfaces **49** and **50**, and a base surface **51** having a curved central portion **52** and outwardly extending end portions **53**, which as shown in FIGURE 5 are generally flat and parallel to the central portion **52**. It is to be further seen from FIGURES 4 and 5 that each insert member **46** has a smoothly swept yoke portion **54** which slopes upwardly from side surface **47** to side surface **48** so that the yoke portion **54** is angularly disposed with reference to the base surfaces **52** and **53**. The contour of the portion or surface **54** continues throughout the curvature thereof and upwardly to smoothly swept shoulder portions **55** and **56** which define a line generally flat and parallel to the line defined by the yoke portion **54** from side surface **47** to side surface **48**.

To summarize, each insert member **46** is provided with a generally flat or straightbase surface **52** as seen by the line *a–b* of FIGURE 5, generally straight or flat base end surface **53**, denoted by the line *c–d* of FIGURE 5 and which is parallel to the line *a–b*, and an upwardly swept yoke or shaping surface **54** which is tapered with respect to the surfaces **52** and **53**, as identified in FIGURE 5 by the line *e–f*. The upper end surfaces **55** and **56**, on the other hand, are similarly tapered or upwardly swept when compared with the surfaces **52** and **53**, and between opposite side surfaces **47** and **48** the surface **55** or **56** is generally parallel with the surface **54**, as denoted by the line *g–h* in FIGURE 5.

To provide the blade shaping means generally designated in FIGURES 2 and 3 by the numeral **33**, the insert members are located in the annular recess **31** of the die member **21** by placing each insert **46** on end on either of the surfaces **49** or **50**, with the surfaces **53** of one insert in abutment with the swept surfaces **55** and **56** of an adjacent insert. This is shown in FIGURES 6 and 7, and it will be seen therefrom that when adjacent inserts **46** are in abutting relation as described, there is defined between the base surface **52** of one insert and the central or yoke surface **54** of an adjacent insert, a blade shaping cavity **57** which is of constant width between surface **52** of one insert and surface **54** of another insert from one end to the other thereof, or from a side surface **47** to an opposite side surface **48**. This arises by reason of the surfaces **53** being essentially flat or straight, whereas

the surfaces 55 and 56 are swept or tapered. As is appreciated, the thickness of the turbine blades from root to tip portions thereof may be varied from the constant dimensions shown by ready modifications of the contours of the insert members 46.

The insert 46 of FIGURES 4 to 7 will generally be found to have the necessary strength properties for most forming operations; however, particular applications may dictate the use of strengthening means on the insert, as is shown in FIGURES 8 and 9. Insert or blade shaping member 58 illustrated therein has generally the exterior configuration of the insert 46 of the earlier described views, and like numerals with the legend "a" appended thereto have been employed to identify like surfaces in FIGURES 8 and 9.

The essential difference between the insert 46 of FIGURES 4 to 7 and the insert 58 of FIGURES 8 and 9 is in the provision or smoothly swept yoke or shaping surface portion 59 of a dam or stop 60 rising upwardly to a height identified in FIGURE 9 by the legend *"j–k"* and located inwardly from the side surface 47*a* a distance denoted in FIGURE 9 by the legend *"j–l"*. The dam or stop 60 then continues toward the opposite side surface 48*a* a distance designated as *"k–m"*, and it will be seen from FIGURE 9 that the surfaces identified by the line *"j–l"*, *"k–m"*, and *"n–o"* are all upwardly swept and parallel to one another. However, these surfaces are tapered or in angular relation with the base surfaces 52*a* and 53*a*. As mentioned, the dam or stop 60 serves to strengthen the insert or blade shaping member 58, and of course, some machining will be required on the turbine blades produced by use of the insert members 58 when the said members are assembled in the manner described in connection with the insert members 46 of FIGURES 4 to 7.

The insert members 46 and 58 of FIGURES 4 to 6 and FIGURES 8 to 9, respectively, are separable members which, when assembled as described, provide therebetween the blade shaping or forming surfaces. In substitution for a plurality of individual members 46 and 58, there may be utilized continuous ring receiving inserts providing therebetween the blade shaping surfaces. This structure is shown in FIGURE 10, and may be seen to comprise a ring member 61 having a plurality of circumferentially spaced and radially extending slots or openings 62 of arcuate configuration and receiving removable insert members 63 of complementary surface contour.

In FIGURE 10 a single insert member 63 is shown in a position of removal from one of the slots 62, as would occur subsequent to formation of a turbine wheel W with a disc portion D supporting the blades B formed integral therewith. However, to provide the blade shaping surfaces with the ring and insert configuration of FIGURE 10, a plurality of inserts 63 are moved radially inwardly to protrude from the inner diameter of the rings 61 a distance calculated in accordance with the length of the turbine blades B desired. The inserts 63 are each provided with a generally concave shaping surface 64 and an oppositely facing convex shaping surface 65, and when the inserts 63 are extended radially inwardly from the inner diameter of ring 61 the desired distance, the shaping surface 64 of the one insert 63 and the shaping surface 65 of an adjacent insert 63 provide therebetween the blade shaping cavity wherein each blade B is formed.

The ring members 61 with the inserts 63 extending radially inwardly therefrom can be employed in die apparatus of generally the type shown in FIGURES 2 and 3. In this application a spacer ring 32 is not employed, however, and the outer diameter of the ring 61 is seated in a recess in the female die member 21. An annular containing ring is suitably secured to the upper surface of the die 21 and extends radially inwardly a sufficient distance to cover both the ring member 61 and inserts 63 therein, so as to not only hold the insert 61 in a firm position, but also to prevent an upward metal flow from between the inserts 63 during the forming operation. After the forging is completed, the insert ring 61 and wheel W locked thereto are removed from the die cavity, and the inserts 63 moved radially outwardly in the manner of FIGURE 10 to free the wheel from the ring. Machining is then accomplished to finish the disc and blade surfaces.

The blank 45 of FIGURE 2 is shown of essentially uniform thickness across the diameter thereof, and it is of course appreciated that sufficient metal mass must be provided in the blank to provide the necessary material for the turbine blades or buckets, and to leave remaining a sufficient body of metal in the disc portion so that the strength characteristics thereof are adequate. In FIGURE 11 there is shown in somewhat exaggerated form in one portion thereof a blank 66 having an annular thickened or raised portion 67 adjacent the outer diameter and on at least one face or surface of the blank 66. The added metal mass 67 provides a sufficient metal body to be extruded to the depth of the blade shaping cavities without drawing excess metal from the blank portion which ultimately forms the disc of the turbine wheel.

In addition to providing a thickened portion such as indicated adjacent the outer diameter of the blank 66 in FIGURE 11, the blank may also have thickened portions radially inwardly of the portion 67 shown in FIGURE 11. A metal blank so constructed is illustrated in FIGURE 12, and is designated therein generally by the numeral 68. The blank 68 may be seen to comprise a reduced diameter central portion 69 and an annular thickened portion 70 radially outwardly of the center portion 69. An additional annular thickened portion 71 may be provided spaced radially outwardly of the thickened portion 70 and connected therewith by a reduced diameter annular portion 72. Radially outwardly of the thickened portion 71 the blank 68 may have a further reduced diameter portion 73 which connects with an annular thickened portion 74 adjacent the outer diameter of the blank 68.

Exemplary apparatus to form the blank 68 into the desired turbine wheel configuration is also shown in FIGURE 12, and comprises a female die member 75 having a shaping surface designated generally by the numeral 76 and corresponding with the configuration of the blank 68. The female die member 75 has an annular recess 77 formed therein which seats blade shaping means 78, which may take the form of either a plurality of abutting insert members 46 or 58, or a ring member 61 with inserts 63 therein as described in connection with FIGURE 10. The blade shaping means 78 is held in position by an annular retaining means 79, which is suitably secured to the upper surface of the female die 75.

Cooperating with the die member 75 is a holddown punch 80 having an active face 81 generally contoured to the upper surface of the blank 68, and a circular punch 82 having shaping surfaces 83, which transmit forging pressures to the annular thickened portions 74 of the blank 68, and metal mass closely adjacent thereto, moving the metal mass in the thickened portion 74 radially outwardly to form the turbine blades or buckets. By the punch and die apparatus of FIGURE 12, the forging tonnage required is reduced substantially, and a blank 68 may be employed which is essentially finish forged except for the raised or thickened portion 74, which is of course shaped to form the turbine blades.

It is of course appreciated that apparatus of the general character shown in FIGURE 12 may be utilized to form the blank 66 of FIGURE 11, and in this event the active surfaces of the die 75 and holddown punch 80 would not be contoured as shown, except to accommodate the metal mass in the relatively thicker annular band 67 on one surface of the blank 66. The turbine wheel produced by formation of either the blank 66 or blank 68 has generally the configuration shown in FIGURE 11, and for purposes of clarity the wheel, disc and blades thereof are

identified by the legends W, D and B, respectively, as in the illustrations of FIGURES 1 and 10.

The turbine wheels W of the FIGURES 1, 10 and 11 comprise a disc D or supporting structure integral with the blades B and formed from the same metal mass which produces said blades or buckets. The disc D of the earlier described turbine wheels thereby provides a hub of the same material as the disc and blades. There arise, however, particular applications in which it is desirable that the hub be of different metal than the rim portion supporting the blades. By proceeding in accordance with the concepts of this invention, a ring or rim portion of sufficient mass in blank form furnishes sufficient material from which to form circumferentially spaced turbine blades which are integral with the rim or ring portion and comprised of the same metallic material.

Such an arrangement is shown in FIGURE 13, and upon reference thereto it will be noted that there is provided an annular rim or ring portion 85 and radially outwardly extending and circumferentially spaced turbine blades 86, providing with the rim portion 85 a turbine wheel structure generally indicated by the numeral 87 and to which a hub portion can be secured along the inner diameter of the rim portion 85 to provide a complete assembly in which the rim or ring portion 85 and blades 86 are of one metal, and the hub portion is of a dissimilar metal. It may be seen from FIGURE 13 that the blades 86 are generally arcuate and of essentially the same configuration as the blades B described in connection with FIGURES 1, 10 and 11.

Apparatus of an illustrative character by means of which the structure of FIGURE 13 may be produced is illustrated in FIGURE 14. As shown therein, a female die member 88 is provided having a relatively shallow cavity 89 with an essentially flat bottom wall 90 therein, the die member 88 further being provided with an annular recess 91 seating blade shaping means 92. It is to be seen from FIGURE 14 that the blade shaping means 92 abut along their outer diameters against a shoulder 93 formed by the recess 91, and that the die member 88 has a shoulder 94 against which abuts an annular blank 95 positioned radially outwardly of a back up punch 96 which meets with the bottom wall 90 of the cavity 89. The blank 95 may be seen to be of uniform wall thickness, and a portion of the thickness thereof is abutted by a retaining ring 97, which additionally functions to maintain the blade shaping means 92 in a firm position in the die member recess 91.

The apparatus of FIGURE 14 further includes an annular or circular punch member 98 which applies forging pressures to the annular blank 95 when the holddown punch 96 is in the position of FIGURE 14. The blade shaping means 92 may take any one of the forms earlier described and in the practice of the method steps employed in the arrangement of FIGURE 14, the back up punch is first moved relative to the die member 88 to engage the inner diameter of the blank 95 and the bottom wall 90 of the die cavity 89. The circular or annular punch 98 is then forced downwardly under the necessary pressures and engages the blank 95 to compress and move the same in a radially outward direction to provide metal mass in the blade shaping cavities provided by individual inserts 46 or 58 or an insert ring 61 of the character shown in FIGURE 10.

As stated earlier, the turbine wheel 87 of the annular configuration shown in FIGURE 13 has the advantage of permitting utilization of different metals for the hub portion than is employed in shaping the rim 85 and blades 86 integral therewith. Further, by use of a ring blank 95, the forging tonnage requirements are reduced by the ratio of ring surface area to the full disc area.

It is to be seen from the foregoing that applicants have provided a novel method whereby proper dimensioning of the turbine wheel structure produced is readily and accurately maintained. The time and cost requirements

of the method are substantially reduced as compared with the casting and broaching techniques heretofore employed and the disclosed process of this invention features a continuous and essentially single step forging, which has marked advantages over the suggested procedure of first forming the blades and then forging a disc thereto. Numerous other advantages will be apparent to those skilled in the art.

Modifications and variations may of course be effected in the process, apparatus and articles disclosed without departing from the novel concepts of the present invention.

We claim as our invention:

1. A method of forming turbine wheels and the like which comprises:

supporting a plurality of blade shaping members against a supporting surface to provide a plurality of circumferentially spaced blade shaping cavities and a female die member cavity with open ends of the blade shaping cavities facing the female die member cavity, inserting a metal blank into the female die cavity spaced from the blade shaping cavities and in contacting relationship with the side walls of the shaping members to cover the open ends of the blade shaping cavities,

applying forging pressure to the end portion of the metal blank to move the peripheral portion of the metal blank radially outwardly into the blade shaping cavities to fill the blade shaping cavities to assume the shape of the cavities and thereby form a plurality of turbine blades integral with a supporting structure therefor.

2. A method of forming turbine wheels and the like which comprises:

supporting a plurality of blade shaping members against a supporting surface to provide a plurality of circumferentially spaced blade shaping cavities and a female die member cavity with open ends of the blade shaping cavities facing the female die member cavity,

inserting a metal blank into the female die cavity spaced from the blade shaping cavities and in contacting relationship with the side walls of the shaping members to cover the open ends of the blade shaping cavities,

retaining the central portion of the metal blank by seating a restraining member on said central portion having a coacting configuration corresponding to the configuration of the central portion, applying forging pressure to the end portion to move the peripheral portion of the metal blank radially outwardly into the blade shaping cavities to fill the blade shaping cavities to assume the shape of the cavities and thereby form a plurality of turbine blades integral with a supporting structure therefor.

3. A method of forming turbine wheels and the like which comprises:

supporting a plurality of blade shaping members against a supporting surface to provide a plurality of circumferentially spaced blade shaping cavities and a female die member cavity with open ends of the blade shaping cavities facing the female die member cavity,

inserting an annular metal blank into the female die cavity spaced from the blade shaping cavities in contacting relationship with the side walls of the shaping members to cover the open ends of the blade shaping cavities,

engaging the inner end walls of the annular metal blank with a backup punch,

applying forging pressure to the metal blank to move the peripheral portion of the metal blank radially outwardly into the blade shaping cavities to fill the blade shaping cavities to assume the shape of the cavities and thereby forming a plurality of turbine

blades integral with a supporting structure with grain lines in the turbine blades continuous with grain lines in the supporting structure.

4. Apparatus for forming turbine wheels and the like from a unitary metal mass to provide turbine blades integral with a supporting member therefor comprising:

a female die member,

a plurality of blade shaping members seated on the die member and defining therebetween a plurality of circumferentially spaced blade shaping cavities adapted to form turbine blades assuming the shape thereof and a female die member cavity,

said blade shaping cavities having open ends facing the female die cavity,

a metal blank adapted to be mounted within the female die cavity and spaced from the blade shaping cavities and contacting the side walls of the blade shaping members before forging pressures are applied thereto to cover the open ends of the blade shaping cavities,

a punch member movable relative to the female die cavity,

said punch member having an outer diameter equal to the inner diameter of the female die cavity, and

said punch member being movable in the female die cavity to apply forging pressures against the blank and move the peripheral portion thereof radially outwardly to fill the blade shaping cavities to assume the shape of the cavities and thereby form turbine blades in the blade-shaped cavities integral with and constituted of the same metal as the mass inwardly of the moved peripheral portion.

5. Apparatus for forming turbine wheels and the like from a unitary metal mass to provide turbine blades integral with a supporting member therefor comprising:

a female die member,

a plurality of blade shaping members seated on the die member and defining therebetween a plurality of circumferentially spaced blade shaping cavities adapted to form turbine blades assuming the shape thereof and a female die member cavity having a recess in the bottom thereof,

said blade shaping cavities having open ends facing the female die cavity,

a metal blank adapted to be mounted within the female die cavity and spaced from the blade shaping cavities and contacting the side walls of the blade shaping members before forging pressures are applied thereto to cover the open ends of the blade shaping cavities,

a punch member movable relative to the female die cavity,

said punch member having an outer diameter equal to the inner diameter of the female die cavity and having a recess therein facing the female die cavity recess, and

said punch member being movable in the female die cavity to apply forging pressures against the blank and move the peripheral portion thereof radially outwardly to fill the blade shaping cavities to assume the shape of the cavities and thereby form turbine blades in the blade-shaped cavities integral with and constituted of the same metal as the mass inwardly of the moved peripheral portion.

6. Apparatus for forming turbine wheels and the like from a unitary metal mass to provide turbine blades integral with a supporting member therefor comprising:

a female die member,

a plurality of blade shaping members seated on the die member and defining therebetween a plurality of circumferentially spaced blade shaping cavities adapted to form turbine blades assuming the shape thereof and a female die member cavity,

said blade shaping cavities having open ends facing the female die cavity,

a metal blank adapted to be mounted within the female die cavity and spaced from the blade shaping cavities and contacting the side walls of the blade shaping members to cover the open ends of the blade shaping cavities,

a first punch member movable relative to the female die cavity,

said first punch member having means to contact the central portion of the metal blank to restrain said central portion, and

a second punch member movable relative to the female die member outwardly of the first punch member, and said second punch member being movable in the female die cavity to apply forging pressures against the end portion of the metal blank and move the peripheral portion thereof radially outwardly while restraining the blank central portion to fill the blade shaping cavities to assume the shape of the cavities and thereby form turbine blades in the blade-shaped cavities integral with and constituted of the same metal as the mass inwardly of the moved peripheral portion.

7. Apparatus for forming turbine wheels and the like from a unitary metal mass to provide turbine blades integral with a supporting member therefor comprising:

a female die member,

a plurality of blade shaping members seated on the die member and defining therebetween a plurality of circumferentially spaced blade shaping cavities and a female die member cavity, said blade shaping cavities having open ends facing the female die cavity,

an annular metal blank adapted to be mounted within said female die cavity substantially spaced from the blade shaping cavities and substantially contacting the side walls of the blade shaping members to cover the open ends of the blade shaping cavities,

a first punch member to be moved into contact with the bottom of the female die cavity through the opening in the annular metal blank,

a second generally ring shaped punch member movable relative to the female die member outwardly of the first punch member, and

said second punch member being movable in the female die cavity to apply forging pressures against the blank and move the peripheral portion thereof radially outwardly to form turbine blades in the blade-shaped cavities integral with and constituted of the same metal as the mass inwardly of the moved peripheral portion.

8. Apparatus for forming turbine wheels and the like from a unitary metal mass to provide turbine blades integral with a supporting member therefor comprising:

a female die member,

a plurality of insert members of generally U-shape seated in said female die member in abutting relation one to the other and defining therebetween a plurality of generally arcuate and circumferentially spaced blade shaping cavities adapted to form turbine blades assuming the shape thereof,

a female die cavity defined by said insert members and said female die member,

said blade shaping cavities having open ends facing the female die cavity,

a metal blank adapted to be mounted within the female die cavity and spaced from the blade shaping cavities and contacting the side walls of the blade shaping members before forging pressures are applied thereto to cover the open ends of the blade shaping cavities,

a punch member movable relative to the female die cavity,

said punch member having an outer diameter equal to the inner diameter of the female die cavity, and

said punch member being movable in the female die

cavity to apply forging pressures against the blank and move the peripheral portion thereof radially outwardly to fill the blade shaping cavities and form turbine blades in the blade-shaped cavities assuming the shape thereof and being integral with and constituted of the same metal as the mass inwardly of the moved peripheral portion.

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