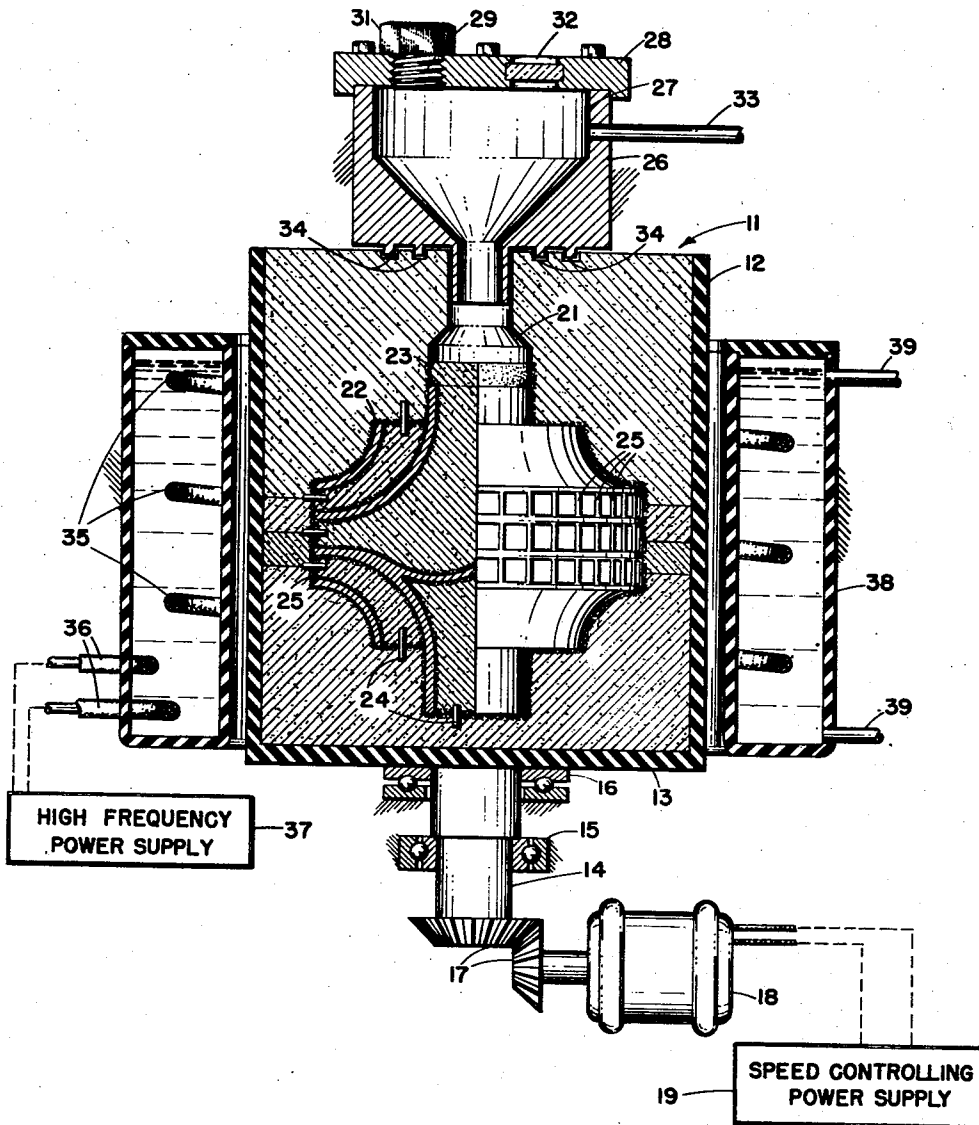


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METHOD OF CENTRIFUGAL CASTING

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METHOD OF CENTRIFUGAL CASTING

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1 This invention relates generally to the art of centrifugal casting of rotary parts and in particular to the casting of turbine and turbo-compressor rotors of high strength and intricate form, in which die casting methods are not readily employed. The method of this invention is suitable for making the turbine rotor of the internal combustion turbine disclosed in the co-pending application Ser. No. 31,778, filed June 8, 1948.

In the construction of turbine wheels of high strength for rotative high speeds, as required for good efficiency, the forms and shapes of practical rotors have been limited by the practical difficulties attending the construction of the rotor elements. Particularly difficult is the construction of hollow members having compound curved surfaces therein and other shapes in which a metallic mold cannot be withdrawn from the molded metallic article. Where the mold is of plaster or other frangible material, prior techniques have not produced molds of sufficient strength for the purpose and it has not been possible to employ centrifugal force of sufficient degree to assure that the molded article is free from gas bubbles, or sufficiently uniform in crystal structure of the article cast therein, for service conditions.

A further difficulty arises in achieving a ferrous casting of proper strength and heat resistance which is at the same time free from oxides of the metals of which the alloy is composed. The presence of such oxides is generally detrimental in the structure, making it non-uniform and weak in the spots affected, such that the cast piece fails in service under stress.

Accordingly, an object of the present invention is to provide a method for forming a rotor element of intricate form and uniform density, pre-stressed and tempered for use at high temperatures and velocities.

Another object is to provide a method for manufacturing a plaster mold of sufficient refractory strength to withstand centrifuging of a high temperature molten fill therefor.

A further object is to provide a method for forming a casting comprising intricate compound curved surfaces without gas bubbles or oxidation products therein.

A still further object is to provide a method for filling an induction heated centrifugal mold under inert gas pressure while the mold is being centrifuged.

Still another object is to provide a method for heat treating a casting under high rotational stress while the casting is confined to precise dimensions within a centrifugal mold.

2 The exact nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawing in which the single figure is a vertical diagrammatic section of one form of mold and controls therefor suitable for use in practicing the present invention.

Referring now to the drawing for illustration of apparatus suitable for employing the method of this invention, numeral **11** indicates generally a mold structure of any desired form for casting an object, especially such objects as are designed for high speed rotation. The mold illustrated **15** has a cylindrical outer surface contained in a reinforcing cylinder **12** of any desired size and supported on a base such as the plate **13** which in turn is supported for rotation on a vertical shaft **14** within bearings **15** and **16** secured as **20** desired to any supporting base.

The mold is rotatable, preferably, about the axis of spin of the rotor element being cast, where high rotary velocities will be encountered in the service use of the casting. The shaft **14** **25** may be driven as desired by a pair of gears **17** and a motor **18** under speed control effected by the controlled power supply such as **19**, whereby centrifuging speeds are controllable at will.

Within the mold is a cavity **21**, in which the casting is formed, and which includes a filling hole in the upper region and communicating with the upper surface thereof. Portions of the casting having interior compound curved surfaces such as **22** are formed by inserted plugs of the molded plaster material such as **23** which may be keyed in place as by keys **24**, of strength sufficient to hold the plugs in place during the casting operations but which may be broken as the mold **11** and cylinder **12** are split open to remove the casting. These outer portions may be reused in further casting operations if desired.

The portions of the casting such as **22** are interconnected as by the partitions **25** which, for most purposes, must provide access inwardly **45** or upwardly from all regions of the casting to permit egress of the gas included when powdered materials are to be fused in the mold, or whenever such gas may form bubbles in the mold cavities within the main cavity **21**. Thus when the mold and casting can be constructed as described, centrifuging the molten material can be caused to expel all gas bubbles. Adequate space is provided above the casting for a surplus of casting material, which may be cut or ground off when the casting is completed, according to conventional practices.

55 A hopper **26** is provided above the mold from

which the metal, or powdered casting material, is directed into the cavity from the funnel 27 therein. The hopper is closed at the top thereof by a cover 28 secured thereto and having a filling hole 29, closed by a top 31 and having a window 32, preferably of refractory material such as fused quartz. A gas inlet 33 is provided for forcing an inert gas into the mold to displace the air therein. Seal rings 34 provide for prevention of excessive gas pressure loss when the mold is rotated under gas pressure.

Coils 35 are supplied through leads 36 with a high frequency induction heating current from the adjustably controlled power supply 37 and are cooled by the water jacket 38 which is fed by tubes 39.

The mold may thus be rotated, heated, filled and subjected to gas pressure, and the centrifuging speed controlled.

The present invention provides a method for producing a uniformly strong casting of ferrous materials which may be of any desired form or structure and possessing the characteristics of high density and small crystal structure. Furthermore, the process herein disclosed provides for tempering the casting under pressure and centrifugal force wherein the force on the casting during cooling thereof is substantially the same as on the finished turbine wheel when operating at service speeds for the production of power. This is a feature of particular importance when the wheel is of internal combustion type such that the wheel is constantly used at high speed and at a temperature near the "creep" temperature. By tempering the wheel in casting, and cooling the wheel under the approximate conditions of use, with respect to centrifugal force and temperature, the tendency to acquire further distortion in the wheel, or "creep," under service use, is limited to a heretofore unachieved degree.

When the power for driving a turbine is derived from gases at very high superheated steam temperatures, or when the driving force is from expanding combustion gases in an internal combustion turbine, there is a major problem of finding materials sufficiently strong and refractory to withstand high temperature such as when the blades and rotor elements of the turbine are subjected to the combined force of the high velocity or high pressure gas and the centrifugal force inherent in the high speeds at which efficient turbines must be driven. These forces cause a distortion of the metal of the rotor elements and this distortion gets progressively more pronounced with continued operation at high temperatures, until rubbing of the parts of the rotor on the stator parts occurs, or until the wheel ruptures and the life thereof is ended. This slow change of dimensions is referred to as "creep" and the lowest temperature at which it occurs is known as the creep temperature.

In this invention the tempering of a rotor element at rotational speeds exceeding the service speeds and at progressively decreasing temperatures is accomplished, the rotor element being continuously held to shape, to improve the characteristics of the rotor and raise the creep temperature of the completed rotor.

The present method further improves molding at high temperature and high centrifugal forces by providing an improved mold consisting of a suitable settable material, for example, plaster which is accurately formed as desired and then set in that form. The formed surfaces which are to come in contact with the molded material

are then treated to improve the surface smoothness or stream flow characteristics and to increase the strength and heat resistance thereof, corresponding to the conditions of service of the cast rotor.

This treatment consists of applying to the formed mold surface a coating of ceramic material such as porcelain, glazing or the like, which is fusible at a temperature above the melting point of the material comprising the casting, but hard and strong at temperatures near that melting point. This coating may be applied as a paste, solution, emulsion or in like form such that the material is deposited in a thin layer over the surfaces of the mold. The mold is then fired or baked at a temperature above the fusing point of the ceramic material, and the ceramic coating is absorbed in the mold surfaces to leave these surfaces of the same dimensions as existed prior to application of the coating thereon.

When the ceramic material cools and solidifies, an impervious and smooth surface of the same dimensions as originally constructed is obtained. The ceramic material employed is applied in one coating or in repeated coatings and bakings so as to cause impregnation of the mold structure with the molten ceramic to any desired depth for causing the strength thereof to be sufficient to withstand the centrifugal forces encountered in casting the rotor element therein while spinning the mold at a particular high velocity.

The ceramic material is not used in excess of the requirement for sufficient mold strength, since, in the construction of intricate forms such as internal combustion turbines, it is necessary to remove the mold from the casting by breaking up the mold. Solid ceramic molds, or sand or plaster molds fully impregnated with ceramic material, would be difficult or expensive to break out of the casting.

A number of methods of removing the mold material from the casting are available at the option of the user, such as sand blasting, high velocity jetting, and use of high velocity pellets blown into the cavities which are to be cleared of plaster and ceramic material.

In the practice of this method of forming and tempering turbine wheels and other high speed rotary objects the mold is conveniently so arranged as to be fillable by gravity feeding of casting materials into the mold. If the axis of rotation of the mold is arranged vertically and the power is fed in by a hopper from above as illustrated, the hopper may be kept partially filled at all times, and the metal, when melted and consolidated by centrifuging, flows into the crevices and corners of the mold to perfectly fill all portions thereof, the mold being kept full at all times by replenishment from the hopper.

After filling the mold it is heated in some suitable manner to fuse the mold material. Applicant finds that this may be most advantageously done by induction heating, and employs electrical coils about the mold, which are energized by a high frequency current in order to confine the heating effect to the interior of the mold where a conductive material carries the induction current. The powdered metal is a good induction heating medium, and quickly fuses as the current is applied to the coils. The size of the molded object for a turbine of large horsepower is quite large and the induction current required is necessarily large, necessitating induction currents of large value. Cooling is therefore re-

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quired for these induction coils, which may be provided in any suitable way such as by forming the coils of tubing and passing water through the tubing, or by surrounding the coils with a water jacket of material effecting small losses of current.

In order to prevent oxidation of the metallic powder and to further improve the distribution of the metal in the mold an inert gas is fed at several pounds pressure to the upper and inner portions of the mold during the filling, fusing of the material and refilling of the mold. For this purpose nitrogen may be supplied from a pressure tank through the filling hopper and into the filling hole for the mold. The hopper is conveniently made detachable so that it may be removed before the casting is cooled. Between the hopper and the mold there may be provided concentric annular brushes of suitable design to permit rotation of the mold and yet seal the mold cavity to prevent large losses of the nitrogen. Preferably, the inert gas is supplied at reduced temperature, and by allowing free flow thereof into the mold after it is filled, but before it is heated to fuse the metal, the air is largely displaced from the metal and mold. This is conveniently continued until the entire mold is reduced in temperature to about the temperature of the inert gas to assure maximum elimination of free oxygen from the interior of the mold. When, for example, nitrogen is supplied from a pressure tank, expansion of the nitrogen provides sufficient cooling for this purpose.

The gas flow thus supplied is continued as the metal is fused and centrifuged, and while refilling takes place to prevent oxidizing of the metal and to assure maximum filling density.

As the powdered metal is fused the mold is rotated at a velocity sufficient to drive the gas bubbles from the mold crevices and corners as the molten metal is centrifugally forced into the outer parts of the mold. The construction is such that a channel is always provided inwardly toward the center of the mold or upwardly toward the mold inlet, thereby preventing trapping of the gas collected during the centrifuging operation. The mold is then filled to the top thereof with additional powder until completely full of molten metal at maximum density.

Having thus filled the mold in a manner to prevent formation of gas bubbles and other defects in the molded structure, and having centrifuged the molten material to assure maximum density, the molten material is cooled under stress comparable to the stress employed in service use of the molded object. To accomplish this the speed of rotation is increased, preferably after removing the feeding means for introducing powdered metal, and for supplying inert gas thereto to facilitate further rotation of the mold. The speed employed thereafter is comparable to the service speeds of the cast member. The induction current is then gradually decreased until a cooling of the mold occurs and the metal solidifies. The cooling is kept under control at all times in accordance with the best practice for tempering the alloy being cast, and the rotation of the mold is continued at the service speeds, or the most desirable speed.

When the heat treatment under controlled temperature and pressure, or centrifugal force, is completed the rotation is stopped and the mold removed from the molded material. In most forms of turbine, for example, this involves

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breaking out the mold to leave the intricate shaped rotor, any suitable method for the purpose being selected as desired. This step completes the manufacture of the turbine rotor or other similar object, and a product of high density, uniform structure, prestressed to any predetermined degree desirable is produced, the product of successive operations performed in this manner being uniform to a degree heretofore not achieved. The strength of a rotor formed according to this method is also greatly enhanced.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Having thus described the invention, what is claimed is:

1. The method of casting a turbine wheel in a precision mold, comprising the steps of filling the mold with powdered casting material, removing air from the mold, rotating the mold at a high centrifuging velocity about the axis of the wheel being formed, induction fusing the formed material during said rotation, maintaining the mold full by supplying additional powdered metal to compensate for the volume lost during fusion, rotating the mold at a higher velocity corresponding to the service velocity of said wheel while cooling the molded material during said higher velocity of rotation, and removing said mold from the cooled wheel.

2. The method of claim 1, and the further step of supplying an inert gas to the material within the mold during fusing and cooling thereof.

3. The method of casting a gas turbine rotor in a precision mold comprising, filling the mold with powdered metal during centrifuging rotation thereof, fusing the powder during said rotation, maintaining the mold full by supplying additional powdered metal to compensate for the volume lost during fusion, increasing said speed of rotation to at least the service velocity for said rotor, and cooling the fused material during rotation thereof at said increased speed whereby the rotor is tempered at stresses approximating the service stresses therein.

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