

April 17, 1962

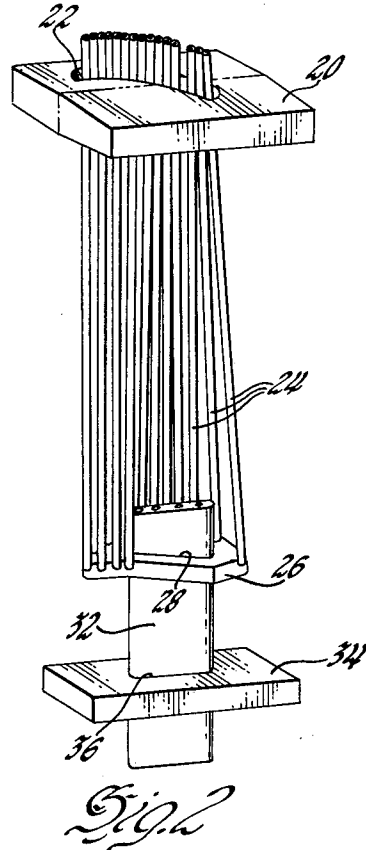
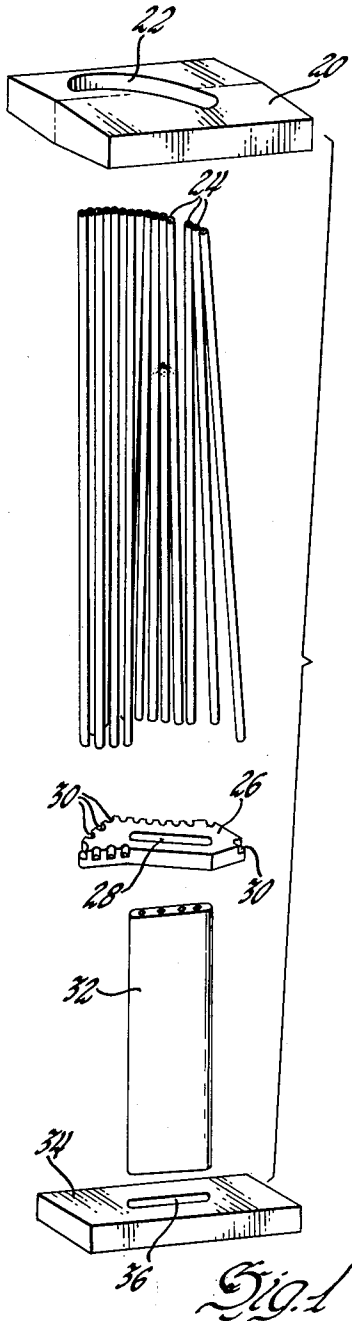
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3,029,485

METHOD OF MAKING HOLLOW CASTINGS

Filed Jan. 14, 1959

2 Sheets-Sheet 1



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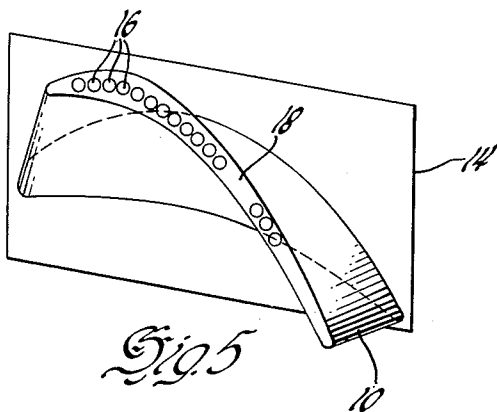
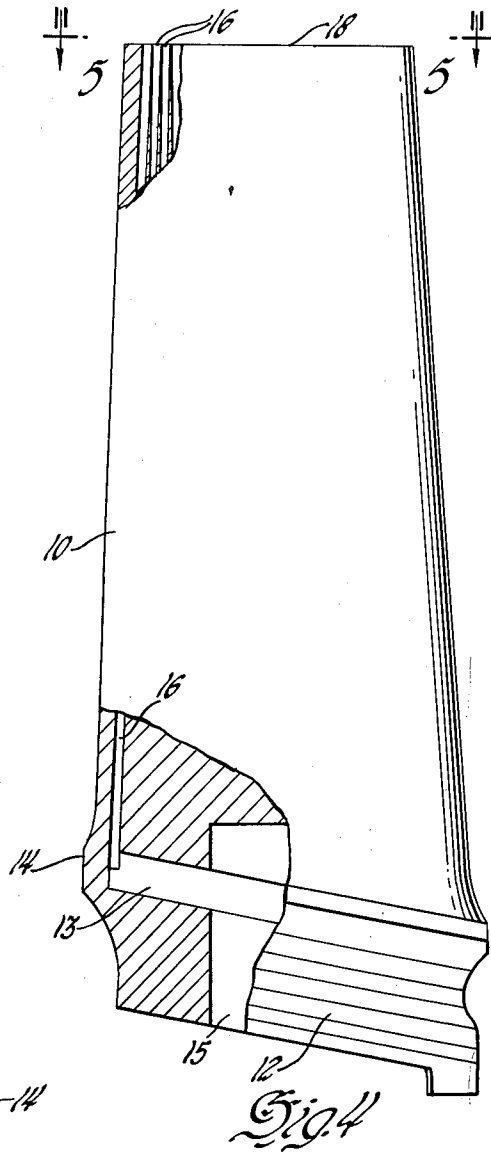
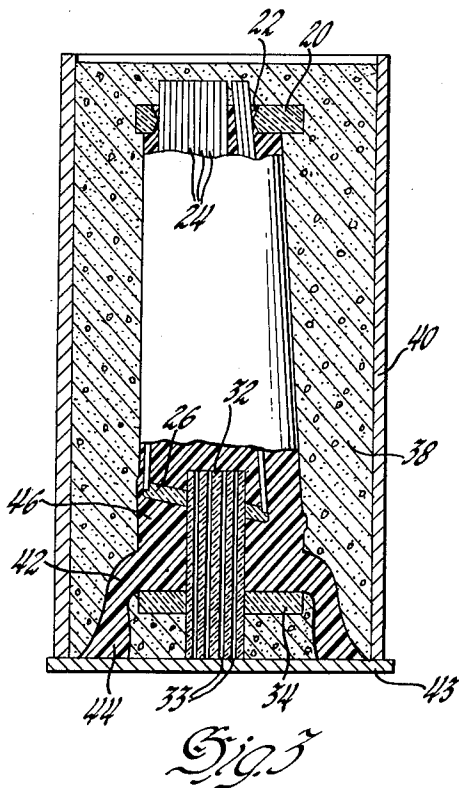
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METHOD OF MAKING HOLLOW CASTINGS

Filed Jan. 14, 1959

2 Sheets-Sheet 2



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3,029,485

METHOD OF MAKING HOLLOW CASTINGS

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Filed Jan. 14, 1959, Ser. No. 786,863

4 Claims. (Cl. 22-160)

This invention relates to a method for making hollow castings and particularly to a method for making turbine blades and vanes, entrance guide vanes and the like which have fluid passages therethrough to provide a cooling means for the blade during the operation of the engine in connection with which it is used.

In turbojet engines a turbine operated by burning gases drives a blower which furnishes air to the burner. Such turbines desirably operate at very high temperatures and the capacity and efficiency of such engines is limited by the ability of the turbine blade to withstand the high temperatures involved. To this end, blades are provided with passages therethrough through which coolant fluids may be passed during operation of the engine. Casting blades of this type presents difficult foundry problems because the blades are relatively thin and have a markedly curved configuration, and the coolant passages must be accurately positioned within the blade structure to efficiently perform their intended function. The coring arrangement to be used in casting such a blade must be capable of withstanding physical handling and thermal shocks in the casting procedures, and must be capable of being accurately and firmly positioned within the investment mold cavity, and be readily removable after casting without detrimental effect on the metal or blade airfoil geometry.

It is an object of this invention to provide a cast turbine blade or the like of the hollow type having a plurality of passages extending from the tip thereof to a plenum chamber located within the platform portion of the blade and having a fluid entry passage leading to the plenum chamber through the root of the blade.

It is a further object of this invention to provide a method of manufacturing turbine blades, compressor blades and the like, having a plurality of passages therein at predetermined positions. It is another object of this invention to provide a coring arrangement for use in casting turbine blades having a plurality of passages therein in an investment molding process, whereby the positions of the passages are accurately controlled and which may be conveniently and efficiently handled in investment molding procedures.

These and other objects are accomplished by providing a core assembly comprising a plurality of elements including a top and bottom core block, each of which is finished to provide locating surfaces for positioning and supporting the core assembly in an investment mold, a plenum chamber core element, a fluid entry element which extends through and is cemented within a slot provided in the bottom block and which extends into and is cemented in a slot in the plenum chamber element, and a plurality of refractory tubes which are cemented in recesses disposed at the periphery of the plenum chamber element and extend to an arcuate slot in the top core block. The arcuate slot in the top core and the recesses of the plenum core element are arranged in a manner such that the tubular core elements, when fitted in place, extend through the airfoil from the periphery of the plenum chamber to the tip of the blade to be made, while being suitably spaced from the walls of the airfoil to provide the airfoil with sufficient strength and a substantially uniform rate of thermal conductivity.

In the process of casting a blade using the above-de-

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scribed core assembly, a wax pattern is molded about the portion of the assembly between the top and bottom blocks which defines the external shape of the blade. After the wax pattern is formed, suitable gating portions are attached to the pattern and the wax pattern is invested in a conventional manner. After the wax portion of the pattern is removed, the tube passage elements, the plenum chamber element and the fluid entry element of the core assembly are firmly supported within the investment mold cavity by means of the top and bottom core blocks. After the casting procedure the core elements are removed by suitable means depending on the type of core materials used.

These and other objects and advantages of the invention will more fully appear from the following detailed description of the invention, reference being made to the accompanying drawings in which:

FIGURE 1 shows an exploded view of the core assembly involved in the present invention.

FIGURE 2 shows a perspective view of the core elements in assembled relation.

FIGURE 3 shows a core assembly having a wax pattern formed therearound which in turn is invested in a refractory mold.

FIGURE 4 is a hollow turbine blade formed in accordance with the invention.

FIGURE 5 is a top view of the blade taken along the line 5-5 showing tubular passages leading to the tip of the blade.

In general the present invention is concerned with a method of casting hollow turbine blades, compressor blades or the like by investment molding procedures. As shown in FIGURES 4 and 5, the blade of the present invention involves an airfoil 10, a shoulder portion 14 and a root portion 12 having suitable serrated or ridged flanks adapted to secure the blade in a correspondingly formed groove or slot in a rotor drum or wheel. The blade is provided with coolant passages 16 extending from the tip 18 of the blade to a plenum chamber 13 located within the shoulder 14 of the blade. A fluid entry opening 15 is provided to the plenum chamber 13 through the root 12. The opening may extend through the root longitudinally of the blade as shown, or alternately it may take the form of a transverse opening through the root portion leading to the plenum chamber.

An important feature of the invention resides in a core assembly, the components of which are shown in FIGURE 1. The core assembly consists of a top block 20 of a generally flat configuration of substantial thickness and having an arcuate opening 22 formed therein, a plurality of lineal tubular core elements 24, a plenum chamber element 26 of a substantially flat and irregular configuration having a slot 28 therethrough and a plurality of recesses 30 arranged thereabout, a flat, elongated fluid entry element 32 and a bottom core block 34 having an elongated slot 36 therethrough.

The top block 20 is preferably formed in a generally rectangular shape and of substantial thickness which may readily be molded and firmly supported within an investment mold. The arcuate slot 22 is of a shape such as to support the tubular passage elements 24 in a position corresponding to the desired position of the openings 16 at the tip of the blade 18 as shown in FIGURE 5. These openings are preferably located midway between the sides of the airfoil at the tip thereof. The arcuate slot 28, as shown in FIGURE 1, is preferably provided with a somewhat V or hourglass configuration so as to permit the fluid passage elements 24 to be readily accurately located therein.

The recesses 30 of the plenum chamber element 26 are located about the periphery thereof and are adapted to support the lineal passage forming elements 24 in a

manner such that the passages formed thereby, although lineal, will pass through the curved blade and follow the contour thereof and extend from the plenum chamber to the tip thereof. It will be noted that the above-described character of the top block opening 22 and the plenum chamber core element 26 makes it possible to vary widely the number and character of the fluid passages to be formed in the blade while utilizing the same basic core structure. The slot 23 of the plenum chamber element and the elongated slot 36 of the bottom block are formed to snugly receive the fluid entry element 32.

The core elements are preferably made of a suitable material which will withstand the molten casting metal, and which may be readily removed by suitable solvents such as caustic solutions which will not appreciably attack the cast metal. Various compounds of silicon including quartz, borosilicate glass and other glasses or suitable ceramic materials may be used. Any suitable extrusion casting or injection molding method may be employed in the manufacture of the core elements. Corning Glass Company Vicor glass tubing is satisfactory for this purpose. Ceramic materials composed of aluminum, silicon and manganese, and sold by the American Lava Company as Al Si Mag 145 and Al Si Mag 670 are suitable for this purpose. These materials may be disintegrated by leaching with a caustic solution.

In the process of casting a turbine blade in accordance with the present invention the core elements are assembled as shown in FIGURE 2 and are cemented together. A refractory cement such as an air setting sodium silicate cement is suitable for this purpose. The fluid entry element 32 preferably is of sufficient length to extend through the bottom block 34 and the plenum chamber element 26 and to extend substantially beyond these elements to provide the structure with rigidity and to facilitate the assembly of the elements. The fluid passage elements 24 are preferably tubular and the fluid entry element 32 is preferably provided with passages 33 therethrough to permit the chemical solvent to enter the elements to facilitate the removal of these elements from the casting by a leaching process as will be more fully described hereinafter.

After the core is assembled, a destructible pattern 46, as shown in FIGURE 3, is formed about the core assembly between the top and bottom core blocks, and the pattern is invested in a refractory mold 38 contained within a metallic container 40 including a base plate 43. The core assembly illustrated, involves the fluid entry core 32 which provides an opening in the root of the blade longitudinally of the airfoil portion. However, it is obvious that the fluid entry core 32 may be readily modified to provide a fluid entry passage transversely of the root. A gating portion 42 having a pouring basin 44 at its outer end is next attached to the pattern, the portions 42 and 44 being formed of a destructible material similar to that of the pattern. It will be observed that the destructible portion of the pattern is cast between the top and bottom core elements 20 and 34, respectively, and these core elements are firmly embedded and supported in the refractory material 38 of the mold.

The pattern 46 is preferably formed of a low fusing substance such as wax or a thermoplastic material, or any other vaporizable, fusible, combustible or otherwise destructible material. However, wax or plastic patterns are preferably employed in order to obtain optimum results. Among the plastic patterns which are satisfactory are those formed of polystyrene, although other thermoplastic pattern materials such as resinous, polymerized derivatives of acrylic acid and methacrylic acid may be used.

The surfaces of the pattern are next coated with a ceramic wash or coating material which is to provide the smooth casting surface on the refractory mold to be formed. This coating material comprises an aqueous

dispersion of conventional finely comminuted refractory materials, a binder, such as an air-setting silicate cement, and defoaming and wetting agents.

Coating of the pattern with the ceramic wash is preferably accomplished by dipping the pattern in the coating solution. Although in some instances the ceramic coating may also be applied by spraying or painting it on the pattern or in any other suitable manner, dipping is preferred because it assures more uniform coating of all the pattern surfaces and is the simplest method of application.

The dip coat slurry is preferably kept in constant motion by stirring means except during the actual dipping operation. However, the mixing action should not be such as to unnecessarily introduce air into the slurry, and care should be exercised in immersing the pattern in the slurry to prevent air entrapment on the pattern. Normally the dip coat solution is retained at room temperature during the dipping operation because excessive heat can result in distortion of the plastic or wax pattern. The excess coating material is permitted to drain off prior to subsequent treatment and investment.

After the pattern has been completely coated with the dip coat slurry, it may be "sanded" or "stuccoed" to provide a rough surface on the coating, thus insuring greater adhesion between the principal refractory portion of the mold and the dip coat on the pattern. This "sanding" may be accomplished by merely screening or otherwise applying silica sand or other suitable refractory materials in known manner to the outer coated surface of the destructible pattern. When all the molding surfaces of the pattern have been effectively covered with sand, the pattern and embedded core should be air dried.

Following the formation of the pattern as above-indicated, a suitable mold 38 usually containing a relatively coarse refractory material is formed about the pattern 46 and the gating portion 42 thereof, the latter being permitted to extend through the wall of the refractory mold so as to permit the escape of the destructible pattern material and to form an ingate for the fluid casting metal. This main refractory mold may be formed about the pattern in any suitable manner and hence, the procedure for forming the mold will not be described in detail. Among the procedures for forming the body of the mold 38, however, is that of mixing the refractory mixture with a predetermined quantity of a liquid binder, pouring it into the sleeve or flask 40 which is preferably vibrated during this pouring operation and then allowing the mold to set. The mold body 38 may be formed of a conventional silica having an ethyl silicate binder or may be formed of any other suitable investment material. An example of an investment dry mix or grog which may be used is one comprising major proportions of a finely ground, dead burned fire clay and silica flour and minor proportions of magnesium oxide and borax glass. The binder for this grog may include an aqueous solution of condensed ethyl silicate, ethyl alcohol and hydrochloric acid.

When the mold body has solidified or set to a sufficient extent, the base plate 43 is removed from beneath the mold and heat is applied to melt the pattern. It is necessary to apply sufficient heat to raise the mold temperature above the fusion point of the pattern material, thus permitting the molten material of the pattern to escape through the gate in the mold formed by the pattern portions 42 and 44.

Upon removal of the pattern from the mold in the foregoing manner, the molten casting metal is poured or otherwise introduced into the mold cavity formed by the pattern. In the majority of instances, it is necessary to pour the casting metal while the mold is still hot. After the molten metal has been poured and the casting solidified, the refractory mold body 38 is broken away to permit removal of the casting. The top and bottom

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core blocks 20 and 34 are also broken away from the casting in the shake-out process.

The casting containing the remaining core elements therein is then immersed in a suitable solvent solution whereby the core elements contained in the body of the casting are dissolved or leached out to form the hollow cast blade. The choice of leaching solution will, of course, depend on the particular core material used.

While the present invention has been described by means of certain specific examples, it will be understood that the scope of the invention is not to be limited thereby except as defined in the following claims.

I claim:

1. A core assembly for making a hollow turbine blade including a blade portion and a root portion, a plenum chamber within the upper portions of said root portion, a fluid entry passage through said root portion to said plenum chamber and a plurality of coolant passages extending from said plenum chamber to the tip of the blade comprising top and bottom core blocks and a plenum chamber core disposed therebetween in spaced relation, a plurality of rod-like passage cores, said rod-like passage cores at one of the ends thereof being disposed in an arcuate slot within said top block and the opposite ends of said rod-like passage cores being supported within peripheral recesses of said plenum chamber core, and a fluid entry core extending within an opening of said plenum chamber core and an opening in said bottom core block.

2. A pattern for use in molding a hollow turbine blade including a blade portion and a root portion, a plenum chamber within the upper portions of said root portion, a fluid entry passage through said root portion to said plenum chamber and a plurality of coolant passages extending from said plenum chamber to the tip of the blade, comprising a core assembly including top and bottom core blocks and a plenum chamber core disposed therebetween in spaced relation, a plurality of rod-like passage cores supported within an arcuate groove of said

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top block core and peripheral recesses of said plenum chamber core and a fluid entry core supported between said bottom core block and said plenum chamber core, and a destructible pattern of the blade formed about said assembly between said top and bottom core blocks.

3. A core assembly for making a hollow turbine blade including a blade portion and a root portion, a plenum chamber within the upper portions of said root portion, a fluid entry passage through said root portion to said plenum chamber, and a plurality of lineal coolant passages extending from said plenum chamber to the tip of the blade comprising a substantially flat top core and a substantially flat bottom core and a plenum chamber core having a substantially flat configuration disposed therebetween in spaced relation, a plurality of rod-like passage cores having the ends thereof supported within an arcuate slot in said top core and having the opposite ends thereof supported within recesses disposed about the periphery of said plenum chamber core and a fluid entry core supported within a slot within said plenum chamber core and a slot within said bottom core, said core elements being firmly cemented together.

4. A pattern for use in molding a hollow turbine blade comprising the core assembly as defined in claim 3 having a destructible pattern of the blade formed about the assembly between the top and bottom core blocks.

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