Sept. 7, 1965 G. D. CHANDLEY 3,204,303

PRECISION INVESTMENT CASTING

Filed June 20, 1963

Fig. 1

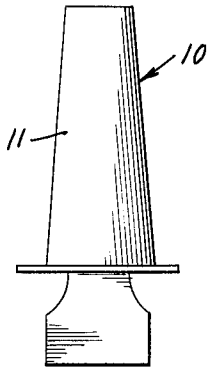


Fig. 2

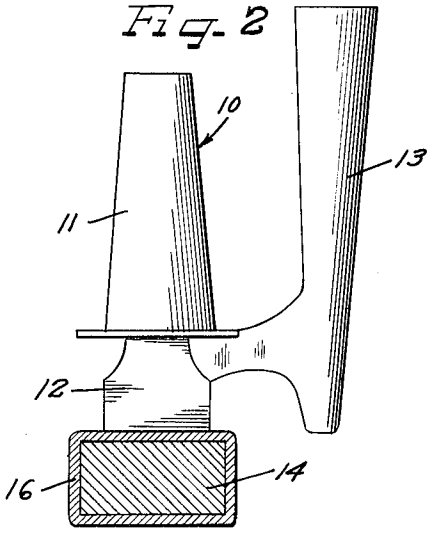
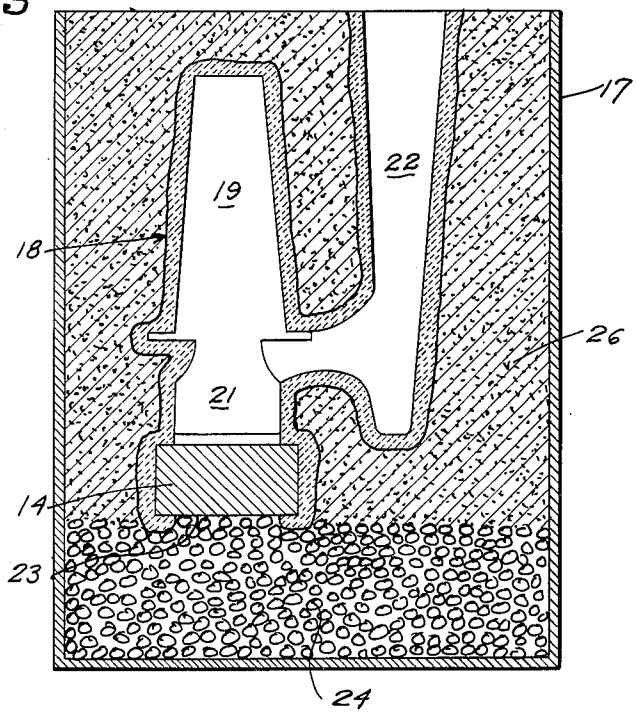


Fig. 3



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PRECISION INVESTMENT CASTING

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The present invention relates to improvements in the art of precision investment casting.

The invention relates particularly to the field of casting metals in which it is imperative to produce a casting with a fine grain structure and maximum soundness.

While the process and apparatus of the present invention are applicable to any article which is made by a precision investment casting technique, it finds particular utility in the casting of articles such as jet engine blades. Such blades may have portions with very thin sections, as well as substantially thick sections. In order to secure suitable grain size and soundness in some portions of the articles, it is necessary to use a high degree of mold preheat and high pouring temperatures for casting. Such conditions have been found to interfere with the attainment of proper grain size and soundness in the thicker or heavier sections of the castings. If lower pouring temperatures are attempted, the thin sections evidence porosity and poor grain structure. Under the conditions of high preheating, the mold does not have sufficient heat capacity to establish good temperature gradients and produce sound, fine grained castings.

The method and apparatus of the present invention are applicable to precision investment casting using various types of disposable pattern material such as wax, mercury, or synthetic resins. The patterns composed of these materials are coated with layers containing ceramic particles and binder materials which, upon heating, serve to bond the ceramic materials together into a self-sustaining structure suitable for use at the high temperatures of molten alloys. In the case of mercury patterns, the ceramic layers applied to the frozen mercury pattern include both a low temperature binder and a high temperature binder, the former serving to provide some coherence to the layers at the temperature of frozen mercury and up to about room temperature, and the latter serving to provide the effective binding material for the mold at elevated temperatures.

One of the objects of the present invention is to provide an improved method for making precision investment casting molds with localized areas of varying degrees of heat conductivity to compensate for the differences in chilling which occur in thin walled and relatively thick walled sections.

A further object of the invention is to provide a method for investment casting which does not require the substantial mold preheating and high pouring temperatures, and still results in a casting having a fine grain size and uniform soundness.

A further object of the invention is to provide an improved pattern composed of a disposable pattern material and having integrally associated therewith a heat conductive material in preselected areas thereof, which material can be precisely located to provide for directional solidification of the casting metal.

Still another object of the invention is to provide an improved ceramic mold assembly having heat transfer means directly embodied in the mold itself to provide proper solidification characteristics for the molten metal in the molding cavity, regardless of the thickness of the section being cast.

Still another object of the invention is to provide an investment casting mold assembly including a relatively thin, ceramic shell mold having a heat conductive metal

embodied therein in proximity to areas of relatively large thickness, in combination with an investment which cooperates with the shell mold to abstract heat from those areas at a greater rate.

In accordance with the present invention, I first form a disposable pattern of the article to be cast and attach to it a chilling material of high heat capacity in those portions of the pattern which have relatively thick cross-sections. The composite pattern and heat conductor assembly is then used as a pattern for forming a ceramic shell mold in the usual manner. When the disposable pattern material is melted out, the heat conductor remains embedded in the resulting shell in proximity to those areas at which a greater degree of heat transfer is to be effected. This composite mold is then placed in an investment which includes a relatively good heat conductor, the latter being in contact with an exposed surface of the heat conductor embedded in the shell mold, whereby the rate of heat transfer from those areas of the mold is increased.

The method and apparatus of the present invention are particularly applicable to the casting of articles such as turbine blades in which the thickness dimension may vary substantially along the length of the blade. In the casting of such blades, it was found difficult to produce a relatively thick section (⅛ inch or more) with uniformly fine grain size and soundness if the conditions of casting were adjusted to secure the proper grain size in the sections of the blade measuring less than ⅛ inch in thickness. It is this type of casting to which the specific examples of the present invention relate although it will be recognized that the invention is applicable to any article in which the same casting problems are presented.

A further description of the present invention will be made in conjunction with the attached sheet of drawings which illustrate a preferred embodiment of the invention.

In the drawings:

FIGURE 1 is a view in elevation of a wax pattern employed for the manufacture of a turbine blade;

FIGURE 2 is a view of the wax pattern of FIGURE 1 after the gate former and the heat conductive body have been attached; and

FIGURE 3 is a cross-sectional view of the finished casting mold supported within a container and ready to receive the molten metal.

As shown in the drawings:

In FIGURE 1, reference numeral **10** indicates a disposable pattern such as a wax pattern in the shape of the article in which the casting is to be made, in the illustrated instance, that of a turbine blade having a relatively thin vane portion **11** and a relatively massive root portion **12**.

As illustrated in FIGURE 2, the pattern **10** has attached to it a gate former **13** which forms the gate in the mold for the reception of molten metal. In accordance with the present invention, the pattern also has atttached to it a metal bar **14** composed of a metal of good heat capacity such as copper, silver, iron, steel, brass, or the like. To secure the metal bar **14** to the pattern **10**, the metal bar **14** is provided with a wax coating **16**, and the two are joined by melting the wax interface and applying a slight pressure.

The cluster shown in FIGURE 2 then forms the composite pattern for the manufacture of the ceramic shell mold. The details of this procedure and the compositions employed do not form a part of this invention as such details are well known to those skilled in this art. Generally speaking, however, high temperature investments usually employ a double slip material. The first slurry used for high temperature molds is applied by dipping or spraying the pattern cluster. This involves using a highly fluid mixture of very fine flours of silica

or quartz plus varying percentages of zirconia, titania, alumina, or other oxides. Included with the solids is a binder such as ethyl silicate or sodium silicate. The vehicle employed may be water, an aqueous alcohol solution, petroleum hydrocarbons, carbon tetrachloride, acetone, or various acids.

The basic ingredients of the dip coat slurry may also be used in the second or backup investment. Such investment also may include fillers to reduce the cost and increase the permeability. Various agents may be added to modify the setting up properties, change the thermal characteristics, or produce investments which have protective chemical agents to modify oxidation, decarburization, or other reactions.

After the formation of the shell mold around the pattern cluster, and melting out of the disposable pattern material, followed by firing of the mold to a high temperature, the completed mold assembly having the form illustrated in FIGURE 3 is disposed in a container **17**. The shell mold which results from the melting out of the pattern and the firing of the ceramic materials has been indicated at reference numeral **18** in the drawings. The shell mold includes a relatively thin vane forming cavity **19** and a relatively thick root forming cavity **21**. A gate **22** for the introduction of molten metal is provided by the formation of the shell around the gate former **13**. The metal bar **14** is embedded within the resulting shell mold in close proximity to the root forming cavity **21** where the problem of heat abstraction is the most serious.

As illustrated in FIGURE 3, a portion of the shell mold surrounding the metal bar **14** is removed to expose the bare metal along a surface **23**. This is done in order to improve the heat conductivity away from the metal bar, as the bar **23** rests in contact with a bed **24** of a good heat conductive material such as steel shot. The remainder of the shell mold is invested in a bed **26** of refractory material consisting of silicates or oxides capable of withstanding the high temperatures involved. Among the numerous materials which can be used are materials such as mullite, magnesia, zirconia, alumina, or quartz. It is generally advisable to use particles having a size range on the order of 1/16 to 1/4 inch.

The invested mold is then ready for the reception of molten metal. Prior to casting, the mold is preheated to a high temperature such as 1900° F. and is allowed to cool in air or vacuum for a short time such as 15 minutes. This procedure establishes very favorable temperature gradients because the metal shot and the metal bar cool very rapidly while the ceramic shell disposed in the refractory grains maintains its high temperature.

The following specific example illustrates the application of the invention to a specific problem.

Example

The article to be cast was a large turbine blade containing sections as thin as 0.012 inch and as thick as 0.500 inch. It was found that a preheat of 1900° F. was required to fill the mold without misrun and without grain size defects. When this preheat was used previously, there was not enough heat capacity in the invested mold to provide directional solidification. When employing an assembly of the type shown in the drawings, a casting was produced which had absolute freedom from shrinkage microporosity and a 3/16 inch maximum equiaxed grain size in the chilled section. The casting metal was a nickel-chromium alloy, and the investment consisted of steel shot while fused magnesia was used as the granular refractory. The mold was preheated to 1900° F. and allowed to cool for 14 minutes. Casting was done in a water cooled vacuum pouring chamber at a temperature of 2975° F.

The process and apparatus of the present invention provide several unique advantages in the field of precision investment casting. The addition of the heat capacity represented by the metal bar eliminates microporosity in sections of relatively high thickness, on the order of 1/8 inch or more. By incorporating the chilling bar directly in the wax pattern and ultimately in the mold, it is possible to precisely locate the chilling bar and maintain the dimensional accuracy of the casting. The joint use of the chilling bar and the shot investment produces a grain size of a type that cannot be obtained when metal is poured conventionally at temperatures necessary to obtain soundness in the thin walled sections of precision castings.

It should be evident that various modifications can be made to the described embodiments without departing from the scope of the present invention.

I claim as my invention:

1. The method of investment casting which comprises forming a disposable pattern of the article to be cast, incorporating a chilling material of high heat capacity in those portions of the pattern which have relatively thick cross-sections, forming a ceramic shell mold about the resulting assembly, melting out the disposable pattern material to form a mold having said chilling material integrally embedded therein, and thereafter pouring molten metal into the mold thus produced.

2. The method of investment casting which comprises forming a wax pattern of the article to be cast, attaching a heat conductive metal to those portions of the pattern which have relatively thick cross-sections, forming a ceramic shell mold about the resulting assembly, melting out the wax pattern material to form a mold having said heat conductive metal integrally embedded therein, and thereafter pouring metal into the mold thus produced.

3. The method of investment casting which comprises forming a disposable pattern of the article to be cast, attaching a chilling material of high heat capacity to those portions of the pattern which have relatively thick cross-sections, forming a ceramic shell mold about the resulting assembly, melting out the disposable pattern material, removing a portion of the shell mold from about said material to expose the same, placing the exposed portion on a bed of relatively high thermal conductivity, and thereafter pouring molten metal into the mold thus produced.

4. The method of investment casting for the production of an article having portions of varying thickness some of which are below 1/8 inch and others above 1/8 inch which comprises forming a disposable pattern of the article to be cast, attaching a chilling material of high heat capacity in proximity to the portions of the pattern in which the thickness is greater than about 1/8 inch, forming a ceramic shell mold about the resulting assembly, melting out the disposable pattern material, and thereafter pouring molten metal into the mold thus produced.

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