United States Patent

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[54] METHOD FOR CASTING DIRECTIONALLY SOLIFIED ARTICLES

9 Claims, 6 Drawing Figs.

[52] U.S. Cl. 164/60, 164/127, 219/10.49
[51] Int. Cl. B22d 25/06, B22d 27/20
[50] Field of Search 164/60, 122, 125, 127, 338, 353, 361; 219/10.49

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ABSTRACT: Articles in which the crystalline structure is directionally controlled as, for example, in directionally solidified or single crystal articles are cast in individual molds with a mechanism to control the cooling rate and direction such that orientation of the crystalline structure is precisely controlled. A graphite susceptor surrounds the individual molds and in cooperation with a chill plate provides the necessary control of the cooling rate and direction.

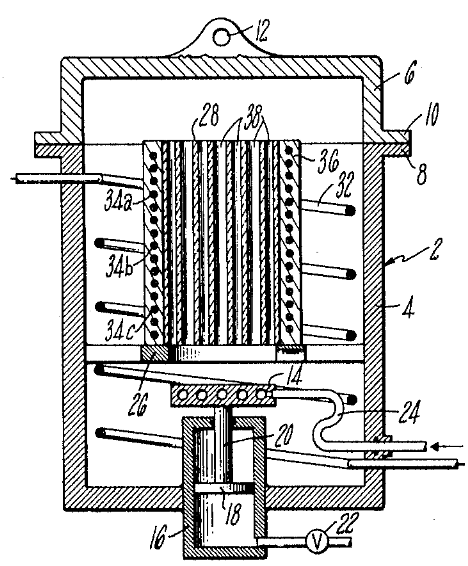

FIG. 1

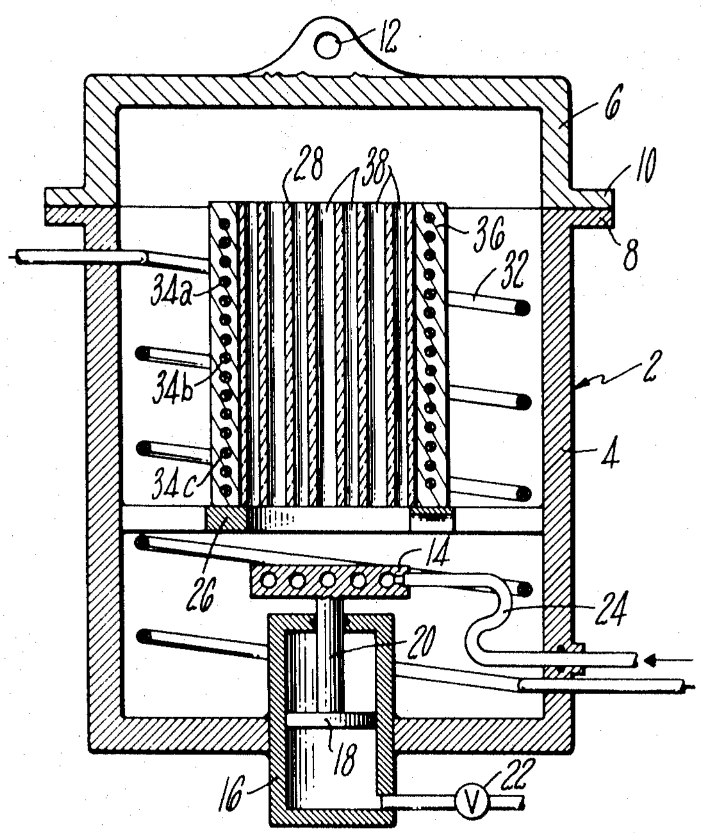

FIG. 2

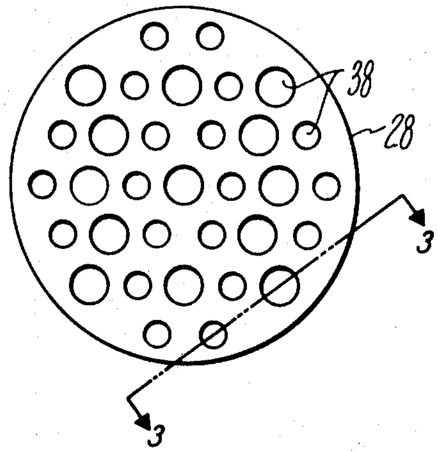

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FIG. 3

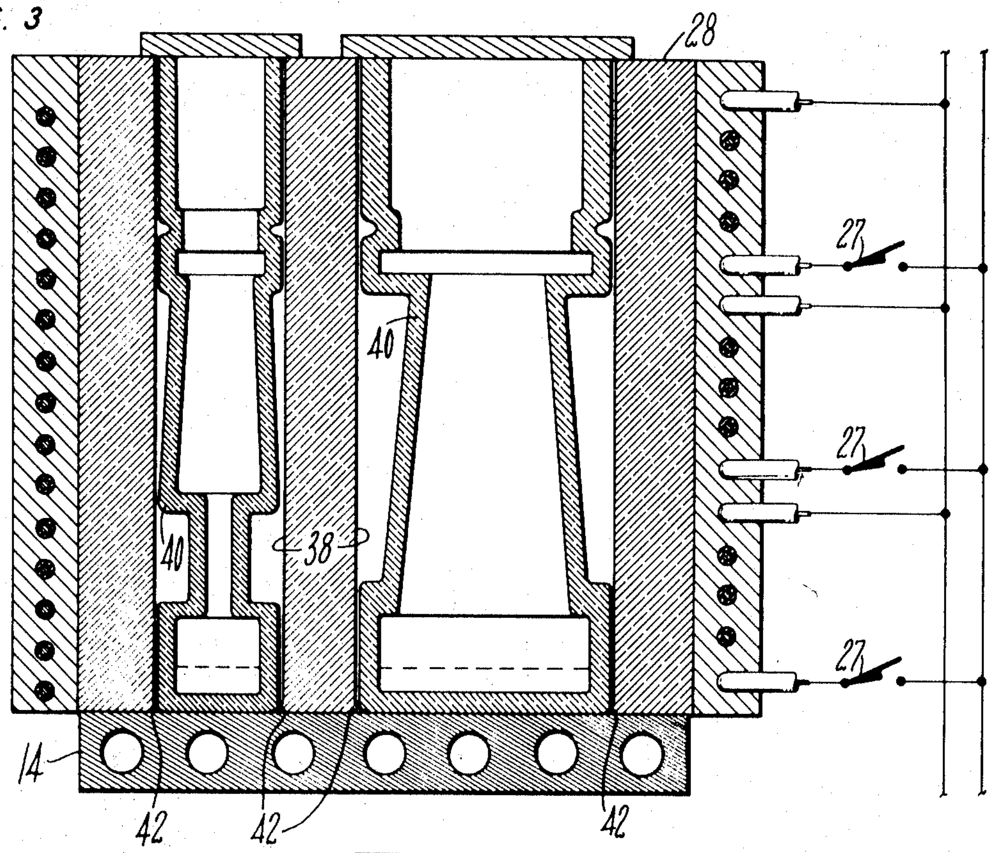


FIG. 6

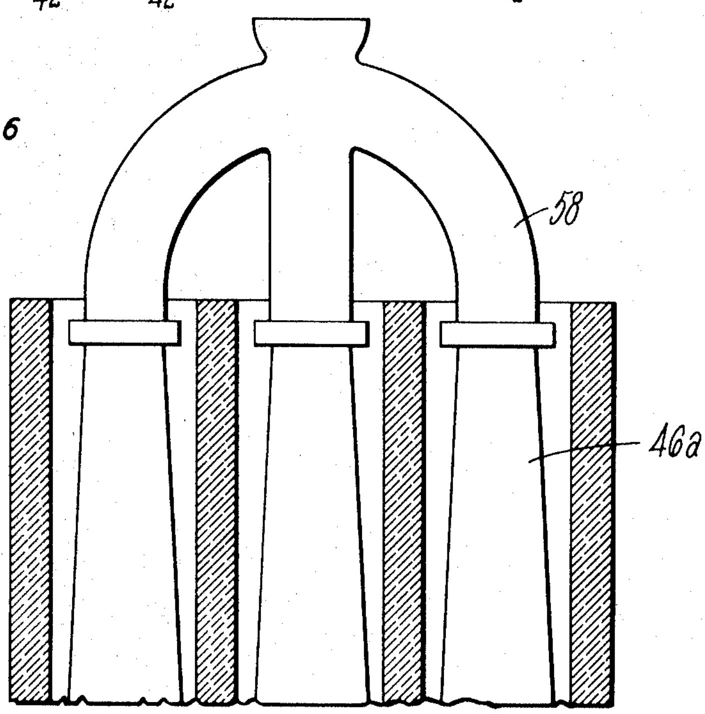


FIG. 4

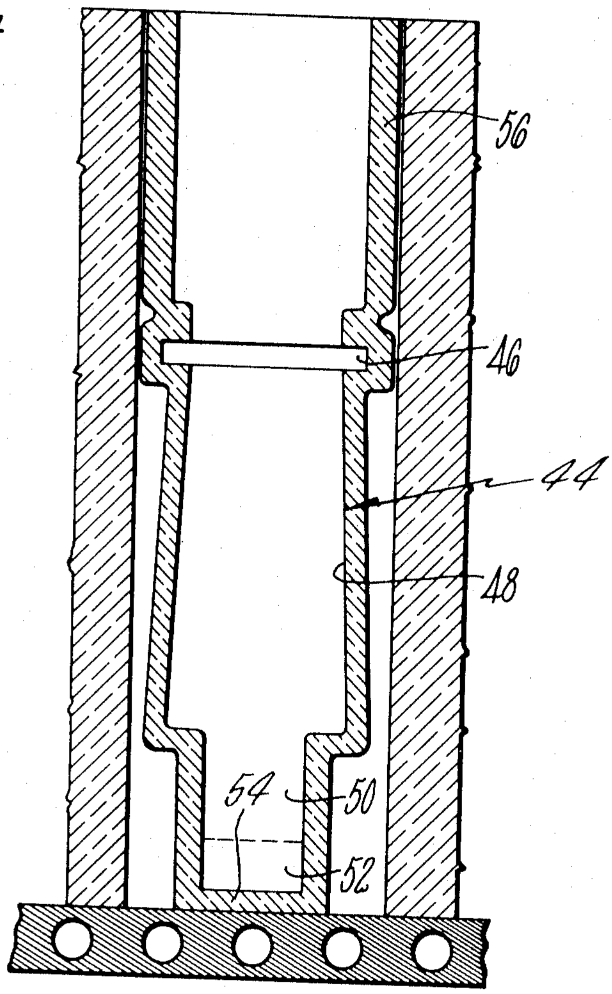
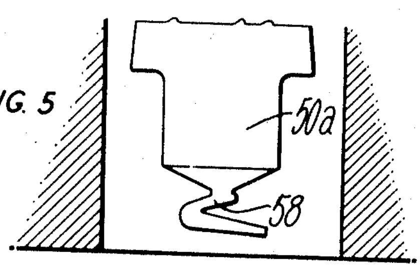


FIG. 5



METHOD FOR CASTING DIRECTIONALLY SOLIFIED ARTICLES

This is a division of Ser. No. 750,335 filed Aug. 5, 1968, now Pat. No. 3,538,981 for Method and Apparatus for Casting.

BACKGROUND OF THE INVENTION

The VerSnyder U.S. Pat. No. 3,260,505 describes the casting of directionally solidified articles such as turbine blades and vanes and the Piearcey application Ser. No. 340,114 filed Feb. 17, 1966, now U.S. Pat. No. 3,494,709 describes the casting of single crystal articles. In either case newly conceived techniques have been required to produce these articles as described in the patent and application. Further experience in casting such articles has led to alternative techniques by which such articles may be produced.

SUMMARY OF INVENTION

A feature of this invention is a casting process by which these articles may be produced singly or in multiples. Another feature is the more precise control of the cooling process in the solidification of the alloys or metals being cast thereby to obtain the desired structure within the cast article.

One particular feature is a casting process for the production of a plurality of cast articles simultaneously in which the alloy in the several cast articles need not be all the same chemical composition and in which both directionally solidified and single crystal articles may be produced in different molds in a single casting process.

One feature is a new form of susceptor for use in performing the casting process.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a sectional view through a vacuum chamber.

FIG. 2 is a plan view of the susceptor.

FIG. 3 is a vertical sectional view through the susceptor along the line 3—3 of Fig. 2 with the heating coils around it.

FIG. 4 is an enlarged view of a mold for directionally solidified casting positioned in the susceptor.

FIG. 5 is a fragmentary enlarged view of a mold for casting single crystal articles.

FIG. 6 is an enlarged view similar to Fig. 4 of a modified form of mold.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A vacuum chamber 2 has attached thereto, not shown, suitable well-known devices for producing a vacuum therein. The chamber has a base portion 4 and a cover 6 with cooperating flanges 8 and 10 for securing the cover in position. A lifting eye 12 may be used for removal and positioning of the cover.

The base 4 has a chill plate 14 mounted therein so that it is vertically movable. In the arrangement this is accomplished by a cooperating cylinder 16 and piston 18, the latter having a piston rod 20 on which the chill plate is mounted. A suitable valve 22 controls the supply of actuating fluid to the piston which, as shown, is effectively a part of the base. Suitable flexible fluid connections 24 provide for a circulation of cooling fluid through the chill plate.

Above the chill plate is a fixed supporting ring 26 on which is positioned a susceptor 28 in which the molds 40, Fig. 3, are positioned. The ring is of such a dimension that the chill plate may be moved upward into contact with the bottom of the susceptor. Within the vacuum chamber is also a heating means such as the resistance heating element 32 for use in heating the chamber. Also, in close surrounding relation to the susceptor are a plurality of axially aligned primary windings 34*a*, 34*b* and 34*c* of induction coils used for heating the susceptor. These coils are suitable supported as by brackets 36 resting on ring 26. These coils are individually controlled by separate switches 27, Fig. 3, as will become apparent, so that the coils may be sequentially turned off from the bottom to the top coil during the solidification of the alloy.

The susceptor 28, as shown in Figs. 2 and 3, is preferably a cylinder which is of a dimension to fit within the induction coils and rest on ring 26. This cylinder has a plurality of axially extending openings 38 therethrough which may be closely spaced leaving only thin walls therebetween. The susceptor is preferably graphite and acts as the secondaries for the primary induction coils. Each opening receives a mold 40, the bottom end of which is approximately in the same plane as the bottom of the susceptor. Spacing above this plane may be used to control the thermal gradients in and rate of solidification in the mold. Suitable projecting elements 42 on the walls of the openings 38 limit the downward movement of the mold within the opening.

The openings 38 are preferably cylindrical and the dimension is such as to fit closely the mold positioned therein. Obviously, if a relatively flat mold were to be used it might be desirable to shape the openings more nearly to the mold shape. The axial dimension of the susceptor is selected to be substantially the same as that of the molds to be used.

Each mold is the shell-mold type and the process for making these molds is now well known. In the present process and apparatus the mold has an article portion 44 that has a cavity conforming to the shape of the finished article. In the arrangement shown the article is a turbine blade having a shroud 46, an airfoil portion 48 and a root 50. Below this article portion and forming an extension beyond the root 50 is a growth zone 52 in the mold. The bottom of the mold has an end closure 54.

Above the article portion of the mold is an extension 56, preferably cylindrical to receive a slug of the alloy to be cast. The length of the complete mold is preferably substantially the length of the opening in the susceptor in which it is positioned. Obviously the volume of the extension 56 is greater than that of the remainder of the mold so that the slug when melted will fill the remainder of the mold.

The mold, as above described, is adapted for directionally solidified articles. A similar mold with a bottom modification will serve for single crystal castings. For this purpose, as shown in Fig. 5, the root portion 50*a* has a different form of growth zone which is a zigzag portion 58 which has been found to produce at single upper end a single crystal that will continue to grow as a single crystal throughout the casting. This zigzag construction is described and claimed in the copending application of Piearcey, Ser. No. 540,114, filed Feb. 17, 1966, now Pat. No. 3,494,709 and having the same assignee as this application.

When the chill plate is moved into operative position in contact with the bottom surface of the mold grain growth starts in the base of the cavity and becomes a single crystal in the zigzag portion with the growth proceeding upwardly on substantially a horizontal liquid-solid interface until the alloy is completely solidified.

A modified form of mold is shown in Fig. 6 in which the mold has the article portion 46*a* and above this, instead of a cavity for solidified alloy, there is a pouring sprue 58 through which melted alloy, from externally of the mold is introduced to the mold. In this arrangement several molds are all interconnected by a spider type of pouring sprue for filling a plurality of molds simultaneously. This arrangement is useable, for example, where all the cast articles are formed from the same alloy.

In use the susceptor with the molds therein is placed in the furnace and heated therein, with the chill plate spaced from the molds until the entire mold has a temperature above the melting point of the alloy and the mold is then filled with melted alloy either by pouring into the mold or molds, Fig. 6, or by the alloy melting from the top cavity and flowing down into the part of the mold in which the casting is formed. With the susceptor and molds above the alloy melting temperature, the alloy will be kept in a molten condition until solidification is started.

To accomplish this the chill plate is moved into contact with the bottom of the susceptor and the bottoms of the mold and at about the same time the lowermost heating coil is turned off. The chill plate cools the bottom of the molds and begins the upward solidification within the molds. At the same time the chill plate also cools the bottom of the susceptor and this takes place at such a rate that the upwardly moving liquid-solid interface between the solidified alloy and the still-liquid alloy above it remains substantially horizontal throughout the entire solidification process.

As the interface moves upwardly successive heating coils from the bottom are turned off to allow the susceptor and the molds therein to be cooled to a lower temperature so that solidification may be completed within the mold. With a susceptor of the type shown and described, it is possible to obtain substantially a uniform temperature throughout the entire susceptor and the molds therein during heating of the molds, and to control effectively the rate of upward cooling of the molds and susceptor during solidification of the alloy in the molds. The rate of cooling and thus the rate of alloy solidification is readily controlled by the heat absorption effect of the chill plate and the rate at which the successive heating coils are cut out during the cooling. The rate of cooling may under certain conditions be controlled by withdrawal of the susceptor from within the induction coils rather than by successively cutting out the coils.

I claim:

1. In the process of producing directionally oriented castings the steps of providing a susceptor having a plurality of parallel openings therein, placing a mold in each of said openings, each mold having an article forming portion heating the susceptor and mold to a temperature above the melting point of the alloy, filling the article forming portion with molten alloy and then bringing a chill plate into contact with the end of the susceptor and with the ends of the molds in the susceptor.

2. The process of claim 1 in which the mold has a slug receiving cavity above the article forming portion to be melted during the heating of the mold and susceptor.

3. The process of claim 1 in which the heating is accomplished in part by a plurality of vertically spaced induction coils around the susceptor.

4. The process of claim 3 in which the induction coils are turned off successively from the chill plate to the top of the mold as solidification of alloy takes place.

5. The process of making, from high temperature alloys, castings in which the crystal structure is directionally oriented as in single crystal or directionally solidified castings, the steps of heating a plurality of molds in a susceptor having a plurality of openings to receive the individual molds therein, each mold having an article forming portion at the bottom heating the molds and susceptor to a temperature above the melting point of the alloy, filling at least the article forming portions of the molds with melted alloy, and contacting the bottom of the molds and the susceptor with a chill plate for solidifying the alloy in the molds.

6. The process as in claim 5 in which each mold has a circuitous passage formed in the mold at the extreme lower end for forming single crystal solidification, and contacting the extreme lower end of the mold with the chill plate to start solidification at this point.

7. The process as in claim 6 with the additional step of providing spaced induction coils around the susceptor for heating the susceptor and molds therein.

8 The process as in claim 7 with the additional step of placing the molds and susceptor in a vacuum furnace for additional heating.

9. The process as in claim 6 with the additional step of making each mold long enough above the article forming portion to receive a slug of alloy thereon, and placing such a slug in the mold prior to heating the mold and susceptor.

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