March 23, 1971 R. B. BARROW ET AL 3,572,419

DOUBLY-ORIENTED SINGLE CRYSTAL CASTINGS

Filed March 13, 1969

FIG. 3

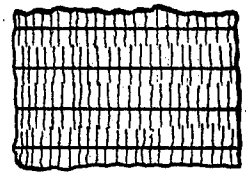


FIG. 4

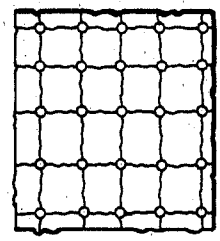


FIG. 2

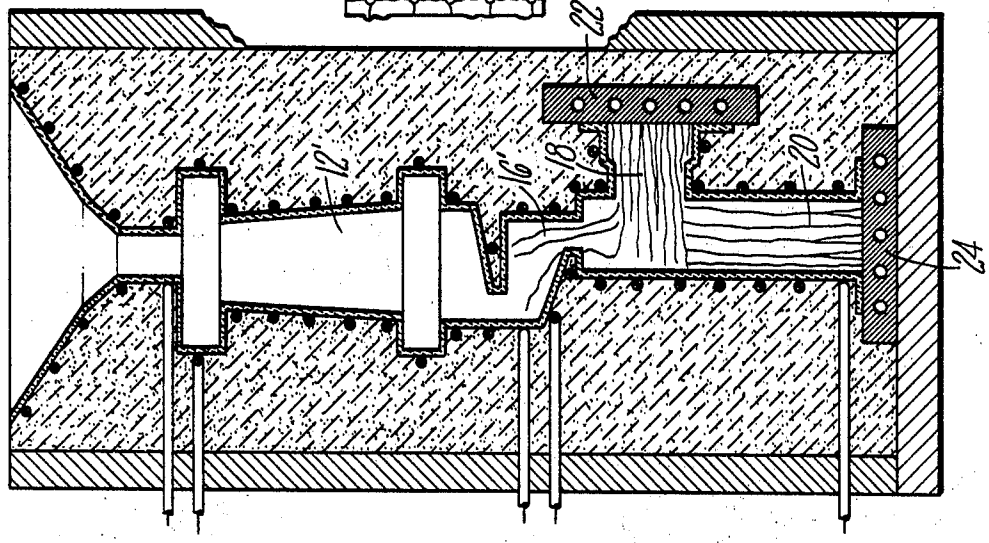
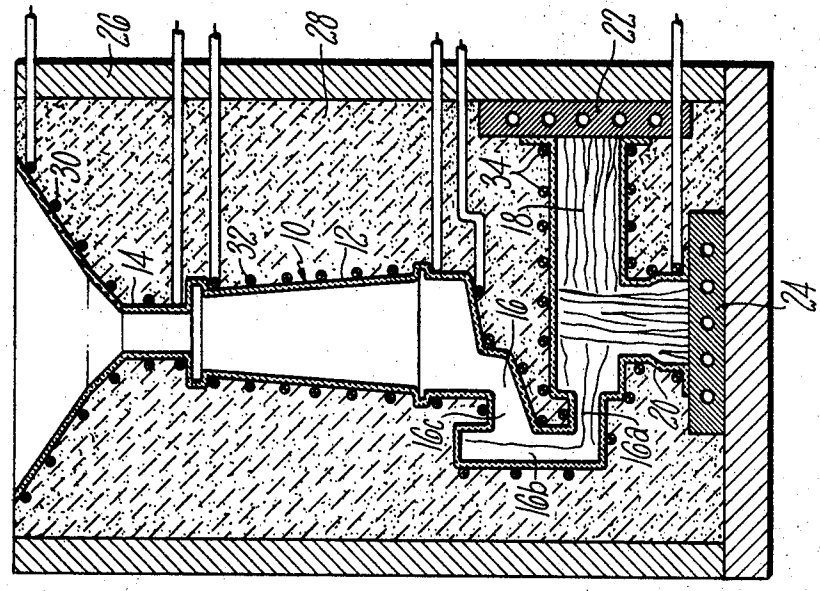


FIG. 1



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DOUBLY-ORIENTED SINGLE CRYSTAL CASTINGS

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ABSTRACT OF THE DISCLOSURE

An apparatus and method by which to produce single crystal parts in which the orientation of the dendritic growth within the crystal in two planes at right angles to one another is described. In effect this produces an orientation in all three right angle planes of the cast article.

BACKGROUND OF THE INVENTION

The copending application of Piearcey, Ser. No. 540,114, filed Feb. 17, 1966, now Pat. 3,494,709, assigned to the same assignee as this application, describes the casting of single crystal parts in which the dendrite growth is oriented with respect to the longitudinal axis of the cast part. However, for certain devices, more precise orientation of the dendrites in a plane at right angles to the longitudinal axis may be essential and may produce, in some particularly stressed parts a superior strength, since the strength of the single crystal castings varies in accordance with the orientation of the dendrites.

SUMMARY OF INVENTION

One feature of the invention is an apparatus by which to selectively orient the dendrite growth and thus the strength characteristics in a particular relation to the part in each of two directions, that is to say, in both a vertical and a horizontal direction with respect to the part as cast. Another feature is a method by which this orientation may be obtained.

A principal object of the invention is the production of single crystal castings in which the crystalline orientation, the dendrite growth, is selectively oriented in each of two directions at right angles to one another.

This invention is in certain respects a modification of that described in the copending application of Sink and Kear, Ser. No. 806,869, filed Mar. 13, 1969, having the same assignee as the present application, which describes the method and apparatus for producing single crystal parts and particularly to parts that can be cast in a mold having a small aperture at the bottom. The present application covers a method and apparatus by which to selectively position the (100) orientation with respect to the several axes of the cast article. This application permits a greater control over the particular orientation of the dendritic growth than in said copending application.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a vertical sectional view through a mold and associated devices embodying the invention.

FIG. 2 is a vertical sectional view similar to FIG. 1 showing a modification.

FIG. 3 is a very enlarged diagrammatic vertical sectional view showing the dendritic growth.

FIG. 4 is a very enlarged diagrammatic horizontal sectional view showing the horizontal dendritic growth.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The doubly-oriented casting is made in a mold **10** having an article forming portion **12**, in this case a turbine blade forming portion, a sprue portion **14** at the top, a single crystal forming portion or constriction **16** and intersecting columnar growth portions **18** and **20** for horizontal and vertical columnar growth, respectively. The ends of the portions **18** and **20** remote from the constriction **16** are open and are closed by chill plates **22** and **24**, respectively. The mold is positioned in a container **26**. The space between the mold and the container is preferably filled with a refractory back-up material **28**, such as Al_2O_3. It will be understood that the mold itself is the type commonly known as a shell mold made by forming a plurality of successive layers of suitable mold material around a disposable pattern that is subsequently removed when the mold is heated for hardening. This is a well-known concept.

In the casting operation the mold is arranged to be heated in such a manner as to produce a temperature gradient between the chill plate and the top of the mold with the heating such that the mold temperature may be gradually reduced as solidification progresses from the chill plates through the constriction and thence vertically through the rest of the mold with the temperature so controlled as to maintain a substantially horizontal solid-liquid interface from the intersection of the two columnar growth portions.

This heating may be by induction or other suitable heating means. The arrangement shown involves the use of several heaters **30**, **32**, **34** surrounding respectively the top portion, the article forming portion and the columnar growth producing portions of the mold, with each heater individually controlled such that the heat input may be reduced successively from bottom to top of the mold as the solidification of the alloy in the mold progresses.

Before pouring, the mold is heated so that it is above the melting temperature of the alloy. Water is then circulated through the chill plates and the alloy with a superheat of about at least 100° above the melting point is poured to fill the mold. The effect of the chill plates and the temperature gradient produced thereby in the mold is to cause the formation of columnar crystalline growth normal to both chill plates as fully described in Ver-Snyder 3,260,505. With adequate super-heat in the alloy and with the heated mold, nucleation is prevented on the side walls of the mold so that the characteristic <001> growth orientation occurs in each growth portion **18** and **20**. By making one growth portion shorter than the other, the grains or dendrites in the shorter one will reach the intersection first and block columnar growth from the longer portion beyond the intersection.

From the intersection, as shown in FIG. 1, the grains from the shorter vertical column grow laterally toward the constriction in a direction perpendicular to their original growth. With both chill plates removing heat from the solidifying alloy the temperature gradient in this portion becomes steeper and a faster growth of dendrites at right angles to both occurs until the less favorably oriented grains are crowded out and the dendritic growth as the constriction is reached is entirely oriented in two intersecting planes at right angles to the two chill plates.

The constriction then serves to select a single crystal for growth into the article forming portion of the mold. The function of this constriction is fully described in the above-noted Piearcey application Ser. No. 540,114.

For the purpose of the present application, it will be understood that the constriction **16** is such that only columnar crystalline growth occurs into the horizontal portion **16***a*. This portion is smaller in dimension both vertically and horizontally than the horizontal growth portion **18** adjacent thereto and only a few grains grow through this portion **16** but of these few grains the dendritic orientation is perpendicular to the two chill plates, being thus oriented in two directions.

From the horizontal portion **16***a* grain growth is vertically through the portion **16***b* of the constriction and only one or two grains exist and grow vertically in this portion. The upper lateral portion **16***c* receives only one grain from the vertical portion and this single grain grows through this portion and into and through the blade (or article) portion of the mold, still in the form of a single crystal and still with the same orientation as in the portion **16***a*. That is to say, the grains or dendrites have the characteristic (001) orientation of the grains adjacent to the horizontal chill plate and the dendritic growth is still at right angles to both chill plates. Thus the blade when solidified has the desired vertical (001) orientation and the horizontal dendritic growth will be in two planes, one at right angles to the vertical chill plate and the other parallel thereto.

FIG. 2 shows a similar arrangement but with the mold construction such that the (001) orientation is horizontal within the article portion of the mold. Thus in this device the mold has the horizontal and vertical columnar growth portions **18'** and **20'** cooperating with the chill plates **22'** and **24'**, and the main difference is that the vertical growth portion **20'** is longer than the horizontal portion between the associated chill plate and the intersection of the two portions. Otherwise the mold is very similar in that the growth portions communicate by constricted portion **16'** with the article portion **12'**. Suitable heating is provided as in FIG 1.

In operation, when the mold is filled with molten alloy, having first been heated as above described, solidification begins at each chill plate and proceeds at right angles to the plates and in a columnar form into the intersection. The grains of the shorter column grow through the intersection first but the dendritic growth is influenced by the columnar growth from the longer column such that dendritic growth occurs out of the intersection in planes normal to both chill plates. The influence of the second chill creates a steep temperature gradient as solidification continues out of the intersection of the columns and promotes faster growth of the grains from the shorter column. When the constriction is reached a single grain is selected and this grows into and through the article forming portion **12'** with the dendritic growth continuing to be at right angles to both chill plates but with the 001 orientation horizontal. Thus in FIG. 2 the article shown is a turbine vane where the major stress axis may be transverse to the air-foil portion thereof, or, in the showing of FIG. 2, horizontal. Most of this type of casting is done by the well-known vacuum casting technique.

Best orientation control is obtained in the direction of the shorter chill growth or column growth so, where a turbine blade is cast in the vertical position of FIG. 1 the shorter column should be vertical to produce a maximum stress axis parallel to the longitudinal axis of the blade. Where the maximum stress axis may be desirably along a shorter dimension as in FIG. 2, the horizonal columnar growth is shorter so the major stress axis will be in horizontal in the cast part. Since the best single crystal growth occurs where the longest dimension of the part is vertically positioned, as the thermal gradient is more readily controlled, the shorter horizontal growth column will assure proper location of the major stress axis.

It will be undestood that this arrangement has particular utility in casting high temperature alloys used in the manufacture of gas turbine parts, examples of such alloys being given in VerSnyder 3,260,505.

We claim:

1. Apparatus for producing doubly-oriented single crystal parts including a mold having an article forming portion, a constriction at the base of said portion, and a growth portion communicating with the constriction, said growth portion including intersecting horizontal and vertical growth passages each open at the ends remote from the constriction, a chill plate closing the open ends of the passages, one of the growth passages being longer than the other between the associated chill plate and the intersection, thereby to determine the orientation of the major stress axis in the alloy cast in the mold.

2. Apparatus as in claim **1** in which the constriction is of such a dimension as to select a single grain to grow into the article portion.

3. Apparatus as in claim **1** in which the longest dimension of the article portion is positioned vertically and the longer columnar growth passage is selected to orient the major stress axis of the cast alloy in predetermined relation to this longest dimension.

4. Apparatus as in claim **1** in which the longest dimension of the article portion is vertical and the shorter growth passage is vertical to locate the major stress axis of the cast alloy in parallel relation to said longest dimension.

5. The method of casting a single crystal part in which the crystalline growth is doubly oriented in said part, said method including the steps of:

establishing intersecting columnar growth in a solidifying alloy in two directions at right angles to one another from chill plates located at right angles to one another,

positioning one chill plate closer to the intersection than the other to give preferred dendritic growth within the intersection,

continuing the solidification beyond the intersection and into an article forming mold.

6. The method of claim **5** with the added step of selecting a single crystalline growth between the intersection and the article forming mold.

7. The method of claim **5** with the added steps of providing a temperature gradient in the direction of solidification and controlling the temperature gradient during solidification from the chill plates to the top of the mold.

8. The method of casting a single crystal metallic article having a selected orientation of the dendritic growth in both a vertical and a horizontal direction, the steps of:

providing a mold having a vertically positioned article forming portion with a constriction at the bottom,

connecting the constriction with a columnar growth mold portion in the form of horizontal and vertically positioned intersecting passages one of which extends beyond the intersection and connects with the constriction,

positioning vertical and horizontal chill plates at the open ends of the passages remote from the intersection,

heating the mold,

pouring an alloy into the mold,

solidifying the alloy from the chill plates through the intersection and thence through the constriction and into the mold, thereby producing in the mold a single crystal part having its dendritic growth oriented at right angles to the planes of the chill plate.

9. The method of claim **8** with the added step of:

making the length of one passage between the inner section and the associated chill shorter than the other, to produce a major stress axis in the cast article parallel to the shorter passage.

10. The method of claim **8** with the added step of:

placing the selected major stress axis of the article portion vertical, and

making the vertical passage shorter than the horizontal passage to position the major stress axis of the cast alloy parallel to the selected major stress axis of the article.

References Cited

UNITED STATES PATENTS

3,346,039	10/1967	Lyons	164—338
3,405,220	10/1968	Barrow et al.	13—27
3,417,809	12/1968	Sink	164—127
3,485,291	12/1969	Piearcey	164—127
3,494,709	2/1970	Piearcey	416—232

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164—127, 353, 361