Dec. 24, 1968 L. W. SINK 3,417,809

METHOD OF CASTING DIRECTIONALLY SOLIDIFIED ARTICLES

Original Filed July 16, 1965

FIG. 1

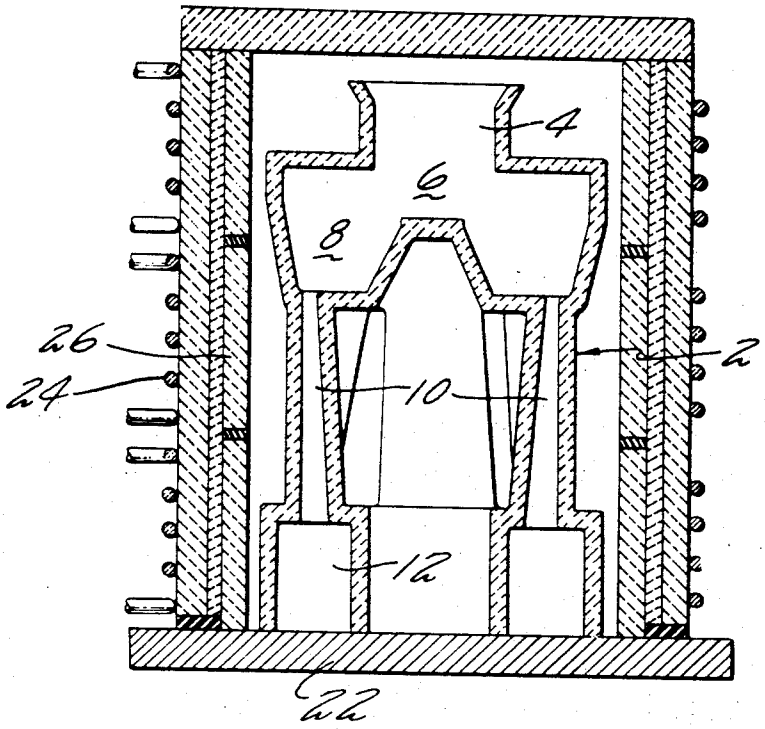



FIG. 2

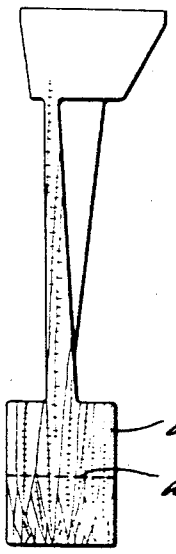



FIG. 3

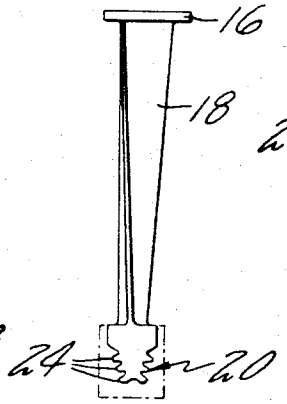
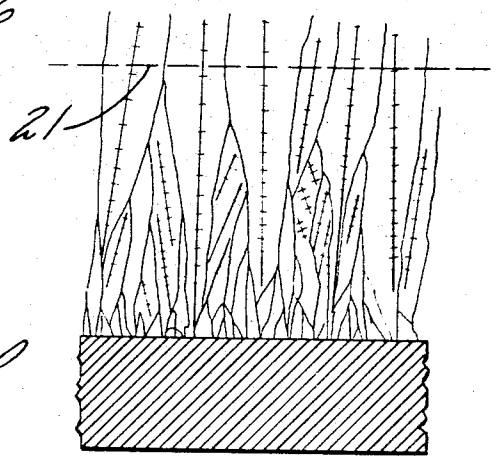



FIG. 4




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# METHOD OF CASTING DIRECTIONALLY SOLIDIFIED ARTICLES

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Original application Ser. No. 472,530, July 16, 1965. Divided and this application June 30, 1967, Ser. No. 662,230

1 Claim. (Cl. 164—127)

## ABSTRACT OF THE DISCLOSURE

A mold and heater for use in producing directionally solidified articles in which the mold rests on a chill plate and the mold cavity includes an extension, adjacent to the chill plate, which constitutes a growth zone for containing the initial random crystallization and in which the growth zone material forms no part of the finished article.

This is a division of the Sink application, Ser. No. 472,530, filed July 16, 1965.

This invention relates to a casting process and to a construction by which to produce a finished cast article having a suitably oriented crystalline structure.

It is well known that superalloy castings under high stress often fail along grain boundaries which are substantially perpendicular to the direction of stress. Under certain conditions, such as in high temperature operation, oxidation or cracking from thermal stress also follows grain boundaries leading to early failure. If the grain boundaries can be positioned in a selected relation to the normal loading of the article, the life of the article, or the strength of the article may be greatly increased. One feature of the invention is a mold construction by which to produce articles having selectively oriented grain boundaries throughout the article.

The concept of producing directionally solidified articles is described in the copening application of VerSnyder, Ser. No. 361,323, filed Apr. 17, 1964, now Patent No. 3,260,505, having the same assignee as the present application. One feature of the present invention is a mold to be used in directional solidification which will contribute significantly to the yield of properly oriented directionally solidified articles. Another feature is a method of casting by which to accomplish this result.

Other features and advantages will be apparent from the specification and claims, and from the accompanying drawing which illustrates an embodiment of the invention.

In the drawing:

FIG. 1 is a sectional view of a mold in a position for casting of articles having selectively oriented grain boundaries.

FIG. 2 is an elevation of the cast article as removed from the mold with the crystalline arrangement shown.

FIG. 3 is an elevation of the finished cast article ready for use.

FIG. 4 is an enlarged sectional view showing the crystalline growth from the chill plate.

The arrangement is shown in connection with the casting of a turbine blade from any one of several high temperature alloys. Such alloys may be, for example, SM200,



B1900, Inco 700 and others. The basic ingredients of such an alloy are, for example:

| | Percent |
|---|---|
| Chromium | 2–25 |
| Cobalt | 4–30 |
| Molybdenum or tungsten | 2–14 |
| Alumimum | 0–9 |
| Titanium | 0–6 |
| Aluminum and titanium, at least | 3.5 |
| Carbon | 0.1–0.5 |
| Boron | 0.005–0.1 |
| Zirconium | 0.05–0.2 |

Balance essentially nickel. Other cobalt alloys are also usable.

It has been found that cast articles may be produced from these alloys in which the grain boundaries extend in a selected direction having a predetermined relation to the loading of the article in use. Thus the turbine blade is loaded in tension and the grain boundaries extend parallel to this longitudinal tensile loading and produce a crystalline structure in which the individual grains extend in parallel relation to one another from end to end of the blade. This is accomplished by causing a controlled crystalline growth from a chill plate at one end of the mold toward the other end of the mold by a controlled cooling of the mold progressively from the chill plate end to the other end.

However, in producing cast articles in this way a small area of the completed casting adjacent the chill plate is randomly crystallized and the directional crystalline growth becomes evident only after a short zone of random crystallization. Therefore the mold has an extension at the chill plate end to form a growth area for random crystallization and to eliminate the critical problem of grain nucleation from the walls of the mold.

Also, where there is a relatively horizontal mold surface near to and facing the chill plate, such as the surface of the mold defining the top surface of the blade root, it is almost impossible to heat this surface to a temperature above the melting temperature of the alloy. The growth zone places this surface at a greater distance from the chill plate so that it is above the melting point of the alloy when the mold is filled and no grains are nucleated at this point. Otherwise, such grain nucleation would produce grain boundaries out of parallelism to the desired direction of gain growth.

As shown in FIG. 1, a shell mold **2** has a pouring sprue **4**, transverse passages **6** to filler tops **8**, a plurality of cavities **10** for the cast articles and a growth area **12** at the bottom. The filler top **8** in each case extends beyond the top of the finished cast article and the bottom portion corresponds in shape to the top of the finished cast article. The latter, in the arrangement shown, is a turbine blade having a shroud **16**, an airfoil portion **18**, and a root portion **20**. The article increases generally in cross-sectional area toward the bottom or root portion. The end of the root portion is clearly shown in FIG. 3 and designated by the dotted line **21** in FIGS. 2 and 4.

The shell mold rests on a chill plate **22** and is surrounded by a heating source such for example as the induction coil or coils **24**, and the graphite susceptor **26** within the circle of the coil.

The lower end of the mold has, as shown, the growth area **12** forming a downward extension of the root portion

20 and being substantially the same cross-sectional dimension and area. This growth portion is selected of such a height that the somewhat random crystalline growth occurring at the start of the casting operation will all have disappeared as shown and the structure in the root and airfoil sections of the blade will all be vertical in the direction of the longitudinal axis of the blade.

Further, the growth zone is of such a height that the horizontal portion of the mold that defines the top surface 28 of the blade root will be far enough from the chill plate that this portion of the mold will be heated during mold preparation to a temperature above the melting point of the alloy. Obviously the greater the spacing of this surface 28 from the chill plate the less heat will radiate from this surface. Accordingly when the mold is filled no grain nucleation occurs in the mold at this point and all the metal solidification begins at the chill plate and proceeds along a substantially horizontal front from the chill plate to the top end of the mold, with the grains having their boundaries all in a substantially vertical axis which will be parallel to the stress axis of the finished cast article.

The casting is performed as described in detail in the copending VerSnyder application, Ser. No. 361,323, above mentioned. The mold is heated by the heating coils to a temperature above the melting temperature of the metal to be poured and the chill plate is kept cool to a temperature less than the boiling temperature of the cooling water circulated through it. When the melted metal is then poured into the mold, solidification begins at the chill plate and the temperature of the mold is gradually reduced from the the bottom to the top of the mold to cause a solid-liquid front in the mold to move gradually from the chill plate to the top of the mold.

After completion of the casting process the casting is removed from the mold, the growth portion 12 is machined off leaving a cast article that is entirely made up of substantially parallel crystals. At the top the portion



above the shroud is machined off to remove the pouring sprue and connecting fingers of metal between the sprue and top extension 8 and leave a finished blade as shown in FIG. 3 except for completion of the required serrations 24 by which the root may be secured within a supporting disc.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claim.

I claim:

1. In the process of casting directionally solidified articles having a columnar crystalline structure substantially parallel to the longitudinal axis of the article and in which the solidification proceeds in a longitudinal direction from a chill plate located at one end of the cast article to the opposite end of the article, the step of providing a growth zone in the casting between the chill plate and the part of the casting forming the finished article such that any random crystallization adjacent to the chill plate is confined to the growth zone and subsequently removing the growth zone from the remainder of the cast article such that the finished article is substantially a columnar crystalline structure.


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U.S. Cl. X.R.

164—353, 361, 371