United States Patent [15] **3,662,810**
Talbot et al. [45] **May 16, 1972**

[54] **METHOD OF INTERNAL NUCLEATION OF A CASTING**

[72] Inventors: **Albert M. Talbot,** Mountain Lakes; **Henry W. Soller,** Dover, both of N.J.

[73] Assignee: **Howmet Corporation**

[22] Filed: **Sept. 2, 1969**

[21] Appl. No.: **854,775**

[52] **U.S. Cl.** **164/57**
[51] **Int. Cl.** **B22d 27/02**
[58] **Field of Search** 164/57

[56] **References Cited**

UNITED STATES PATENTS

3,438,820 4/1969 Goss et al. 148/110

Primary Examiner—J. Spencer Overholser
Assistant Examiner—John E. Roethel
Attorney—Pennie, Edmonds, Morton, Taylor and Adams

[57] **ABSTRACT**

This disclosure relates to methods for nucleating castings to control their grain formation and teaches the addition of a slug of solid material to the superheated melt shortly before pouring for the purpose of forming and maintaining crystalline dendrite fragments in the melt during and after it has been poured into the mold.

4 Claims, No Drawings

METHOD OF INTERNAL NUCLEATION OF A CASTING

BACKGROUND OF THE INVENTION

The controlling of grain formation in metal alloy castings is important to obtaining the desired physical properties of the solidified casting and in turn the desired characteristics of the parts which are made from the castings. The properties influenced by grain structure include tensile strength, hardness, ductility, yield strength, fatigue resistance and stress rupture life. Generally the physical properties of castings are improved by reducing the size and increasing the uniformity of the grains formed therein. It has been recognized for some time that the grain size of metals and other polycrystalline materials in the as-cast condition can be improved by use of mold coatings and by the addition of particular substances to control the growth of crystals in the melt after it has been poured in the mold.

An alloy melt, upon cooling to the temperature at which it became molten, may not solidify at once, but instead may subcool considerably before solidification proceeds from minute particles, known as nuclei, which form or are present in the melt. Immediately below the melting point is a metastable temperature zone in which the alloy melt will not nucleate spontaneously. In the absence of suitable foreign particles or particles of the same substance which might be added, solidification will not occur until the melt has cooled to a temperature below the metastable zone, whereupon nucleation will occur spontaneously. The final grain size obtained will depend on the relative rates of spontaneous nucleation and crystal growth. If nucleation is rapid compared to crystal growth, a fine grain size will result. If crystal growth is rapid compared to nucleation, large grains will be formed.

Prior methods including the use of surface nucleation and internal nucleation have not provided a satisfactory and practical control of grain growth in alloy castings.

SUMMARY OF THE INVENTION

Broadly, the present invention comprises the method of melting a quantity of a constituent alloy which quantity is substantially equal to the amount required to fill the mold to be poured, heating the quantity of alloy to a temperature sufficient to completely melt all constituents of the alloy, placing into the melt a small solid quantity of an alloy including constituents of the melted alloy quantity, permitting the solid quantity to partially go into solution and then pouring the melt including contained crystalline residue fragments into the mold.

It is a feature of the invention that the method may be effectively used in making castings which have both large and small cross sectional dimensions.

The inventive method is particularly applicable to alloyed compositions since they include a plurality of components having different melting temperatures in which unmelted crystallizers of higher melting components of the alloy can function, under the controlled conditions herein described, as grain forming crystallizers.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the practice of our method, the first step is to determine the amount of alloy required to fill the mold to be poured. Then, an amount substantially equal to the determined amount of alloy is placed in a melting crucible. The alloy may be introduced into the crucible in any suitable form, such as in ingots, bars, etc. and preferably, the amount of alloy melted is about **85** to **90** percent of the determined quantity, though it has been found that the amounts varying from just below **100** percent to slightly less than **90** percent provide satisfactory results. This initial quantity of alloy is heated to a temperature above the liquidus or melting temperature of the alloy.

After the melt has been held at a superheated temperature for a sufficient time to provide a substantially uniform temperature throughout the melt, there is added to it a solid quantity of alloy having substantially the same composition as the melt. The slug is added a short time before pouring by introducing it quickly into the liquid, preferably by lowering the suspended slug to allow it to enter the melt. As the slug absorbs heat from the surrounding molten alloy it commences to transform into a generally liquid state. As this melting and change of state proceeds nuclei are formed which precondition the vehicle for the later formation of numerous small equiaxed grains. Since the slug takes on heat as it fuses the temperature of the melt descends closer to its initial solidification temperature.

The descending temperature of the melt as the slug fuses or liquefies the size of slug in relation with the rest of the charge to be poured and the manner of fusion residues of the slug remaining provides the conditions under which the nuclei are formed and maintained for a sufficient period of time for pouring and for the early stages of grain formation in the casting. By adjusting the size of the slug in comparison with the rest of the melt and varying the superheat temperature of the melt prior to the slug addition, optimum control of the formation of crystallizers can be determined for specific alloys.

Since the formed nuclei will remain in the melt for only a short period of time after it has been poured, it is important that the melt be poured soon after the slug is first introduced into the melt. More than one slug may be used provided the volume of solid material added is adequate and each slug is of sufficient size to provide nuclei as it liquefies in the melt. The slug may be composed of material including less than all components desired to be included in the alloy of the casting completed and the proportions of the components of the slug may vary provided sufficient nuclei are formed in the melt.

The quantity of melt prepared using this method may be greater than the amount required to fill the mold or molds to be poured; however, the slug of proper portion to the melt must be added just prior to the pouring or pourings to be made.

Inasmuch as metallic nuclei are continually going into solution, but at a reduced rate as the temperature of the melt drops, it is important that the "seeding" slug continue to constantly replenish nuclei so that upon pouring sufficient nuclei may be dispersed in the melt at the time of pouring to accomplish the desired fine crystallization. Distribution in the melt is materially helped if electro-dynamic stirring is available in the melt such as in an induction furnace crucible. This method of melt nucleation or inoculation is generally applicable regardless of alloy composition or melting method. In each case the pouring temperature is substantially above the liquidus.

EXAMPLE I

A mold requiring **25** pounds of alloy was poured using our method. First, 22.5 pounds of the alloy (90 percent of 25 pounds) was melted in an induction crucible and brought up to a temperature of about 2,750° F. which is 300° F. above the liquidus or melting temperature of the alloy. After the melt was held at this temperature for about 2 to 4 minutes to assure that an even temperature has been reached throughout the melt, there was then added to the melt a 2.5 pound solid slug of alloy having the same composition as the rest of the melt. The ratio by weight of the melt to slug was 10 to 1. A ratio of between 10 and 20 to 1 is preferred in practicing the invention. The slug was at room temperature, about 70° F., when added to the melt and the slug was withdrawn occasionally to inspect its melting progress. The same depth of immersion of the slug in the melt was maintained.

Within a minute after the immersion of the slug approximately 60 to 75 percent of it had liquefied in the melt. At the end of the 2 ½ minute immersion period, the seeded or conditioned melt was poured into the mold which had been heated to a suitable temperature. Unmelted slug material was kept from entering the riser portion of the casting in order to prevent interference with proper feeding of the casting by pouring the melt through a perforated ceramic core plate which retained the residue slug material.

The casting formed was examined and found to have small equiaxed grains throughout.

EXAMPLE II

The same procedure was followed as in the formation of the casting of Example I except the melt was superheated to 150° F. instead of 300° F. above the melting temperature and the pouring was done at about ½ minutes after introduction of the slug. The temperature of the melt after introduction of the slug and just prior to pouring was 75° F. above the melting temperature of the alloy.

The casting formed had small equiaxed grains throughout.

In forming castings having relatively small cross sections, such as certain turbine blades, uniform filling of mold cavities is desired to assure proper grain structure in all areas of the casting. This may be accomplished by mounting the disposable pattern to prevent splashing of the melt as it is bottom poured and to assist the uniform filling of the mold without unnecessary turbulence of the alloy as it enters cavities of the mold. Mounting of the casting is arranged to assure that sufficient nuclei are present in all areas of the casting as it solidifies.

WE CLAIM:

1. A method for controlling the formation of grains in alloy castings by producing a plurality of grain producing nucleating particles in the alloy melt comprising;

a. melting in a suitable container a quantity of an alloy which has a volume slightly less than that required to fill the mold to be poured;

b. stabilizing the melted quantity at a temperature above the melting point of the alloy;

c. placing into the alloy melt a quantity of solid alloy material in which the weight ratio of initial melt to the solid alloy material is from about 6:1 to 20:1;

d. permitting the solid alloy material to partially liquefy to an extent where nucleating particles form in the melt to be poured; and

e. pouring the charge into the mold while retaining residue solid alloy material in the charge during pouring to promote replenishment of nucleating particles and preventing the residue of solid alloy material from entering the mold.

2. The method of claim 1 in which the weight ratio of initial melt to the solid slug is between 10 and 20 to 1.

3. A method for controlling the formation of the grain structure in a casting formed of an alloy having a plurality of components with differing melting temperatures comprising;

a. heating an alloy melt to a temperature above its melting temperature;

b. maintaining the alloy melt at about such temperature for a period of time sufficient for such temperature to be reached substantially throughout the melt;

c. heating the mold to a specified temperature;

d. introducing into the alloy melt an unheated solid slug of alloy metal having substantially the same composition as the alloy melt and in which the weight ratio of initial melt to solid slug is from about 6:1 to 20:1 such that it will reduce the temperature of the alloy melt to a temperature at which small unmelted nuclei of the high melting components of the alloy will be formed and briefly maintained as the slug loses its solid state; and

e. pouring the inoculated melt into the heated mold while retaining residue of the solid slug of alloy material in the inoculated melt during pouring to promote replenishment of nucleating particles and preventing the residue of the solid slug of alloy material from entering the mold.

4. The method of claim 3 in which the temperature of the liquid portion of the charge at the time of pouring is above the melting temperature of the alloy.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,662,810 Dated May 16, 1972

Inventor(s) Albert M. Talbot and Henry W. Soller

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Last Page:

Column 3, line 8, "about 1/2 minutes after" should read --about one and a half minutes after--.

Signed and sealed this 5th day of September 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents