United States Patent [19]

Petrov et al.

[11] **3,857,436**

[45] **Dec. 31, 1974**

[54] **METHOD AND APPARATUS FOR MANUFACTURING MONOCRYSTALLINE ARTICLES**

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[22] Filed: **Feb. 13, 1973**

[21] Appl. No.: **332,208**

[52] **U.S. Cl.** **164/60,** 164/361

[51] **Int. Cl.** **B22d 25/06**

[58] **Field of Search** 164/60, 122, 125, 126, 164/127, 361

[56] **References Cited**

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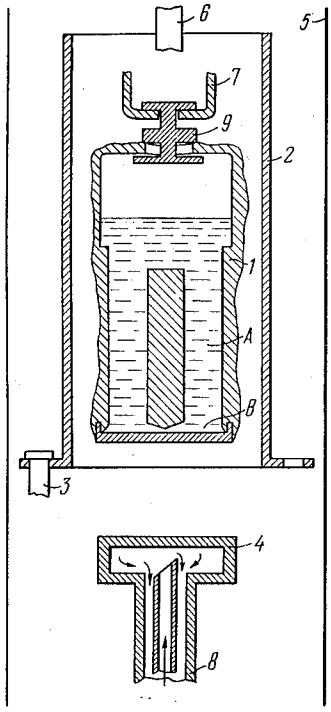
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Primary Examiner—Andrew R. Juhasz
Assistant Examiner—John E. Roethel
Attorney, Agent, or Firm—Holman & Stern

[57] **ABSTRACT**

A method comprising pouring of molten metal into a mould, cooling of its base and subsequent cooling of the mould from the bottom up for crystallization of the melt. This method is carried out in an apparatus comprising a mould having a main cavity "A" following the shape of an article, and an auxiliary cavity "B" made in the form of a downwardly diverging truncated cone which has a horizontally extending wedge-shaped projection disposed at the lower base of the cone. The mould base is cooled by gradually moving a chill from the underside towards the mould. In so doing a sole natural nucleus of the article crystal is formed at the point of the wedge-shaped projection, which rapidly propagates over the perimeter of the base thereby preventing the formation of parasitic crystals.

10 Claims, 21 Drawing Figures



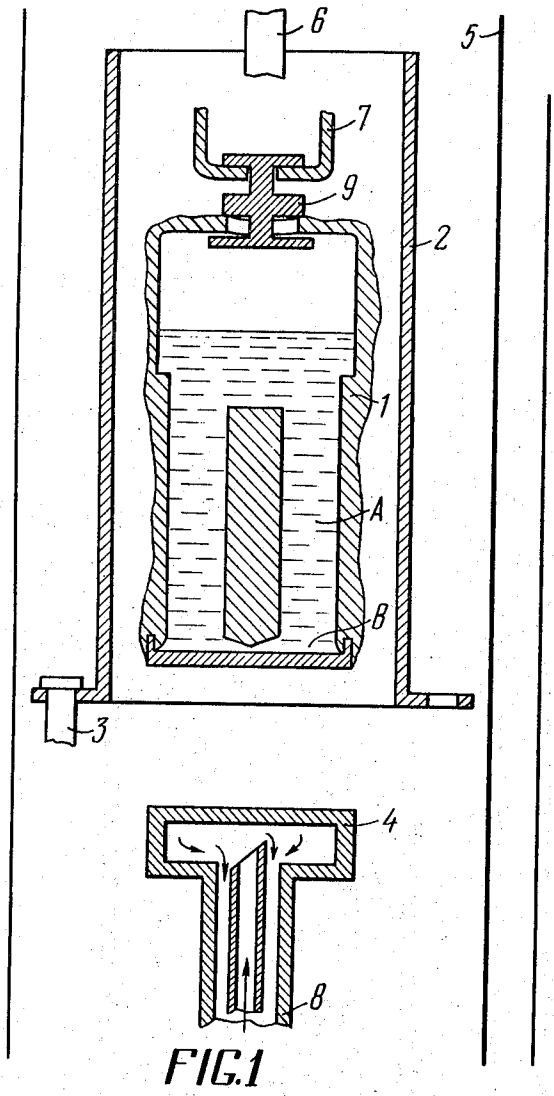


FIG.1

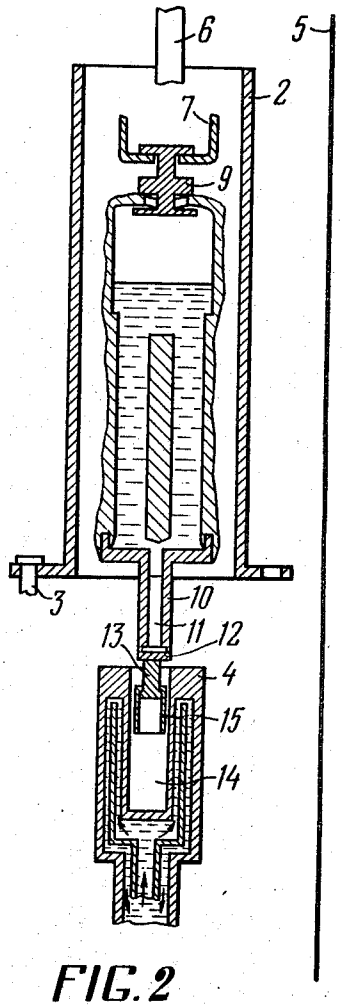


FIG.2

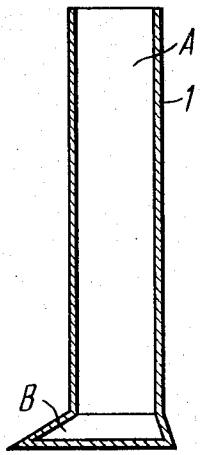


FIG.3

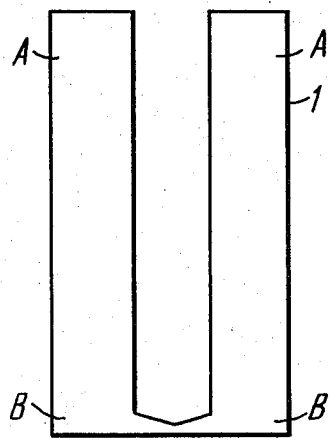


FIG.4

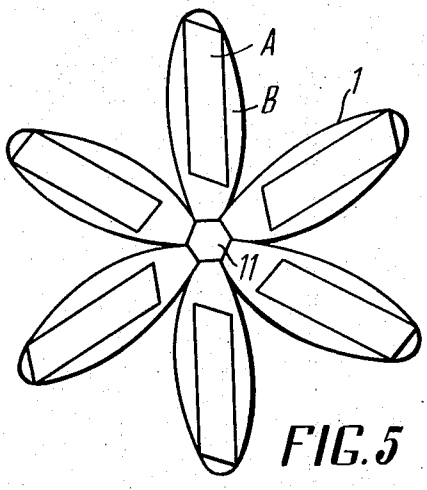


FIG.5

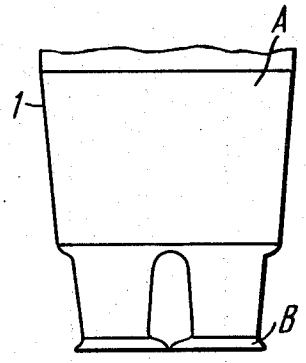


FIG.6

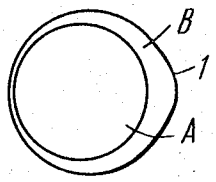


FIG. 7

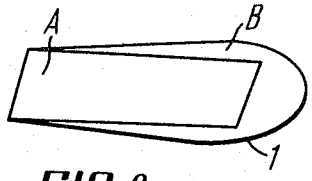


FIG. 8

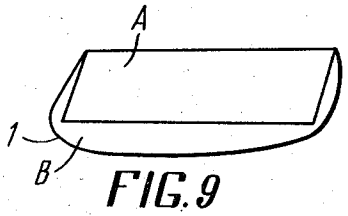


FIG. 9

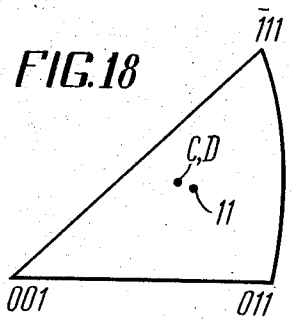


FIG. 18

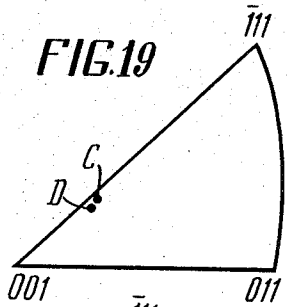


FIG. 19

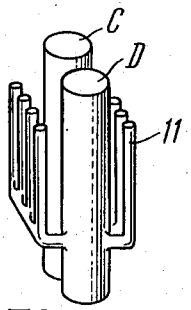


FIG. 21

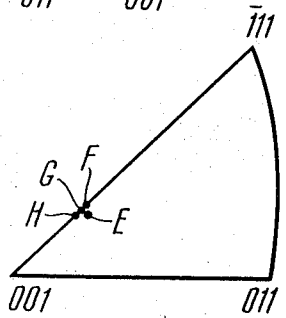


FIG. 20

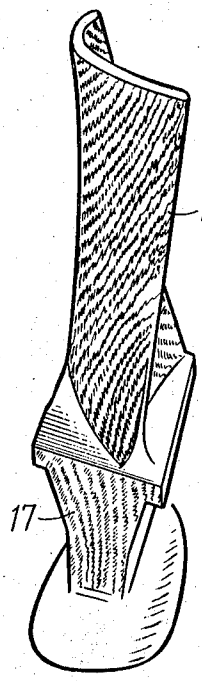


FIG.10

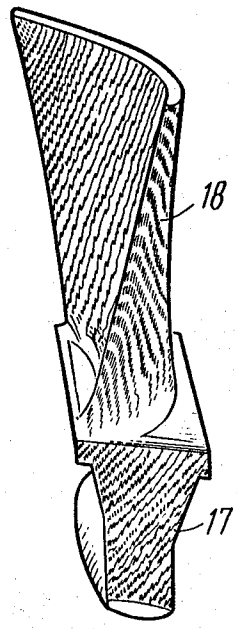


FIG.11

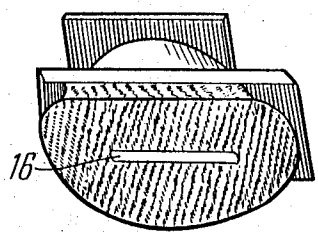


FIG.12

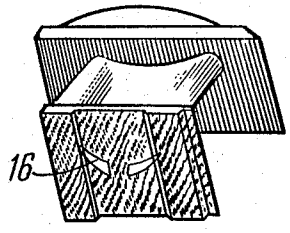


FIG.13

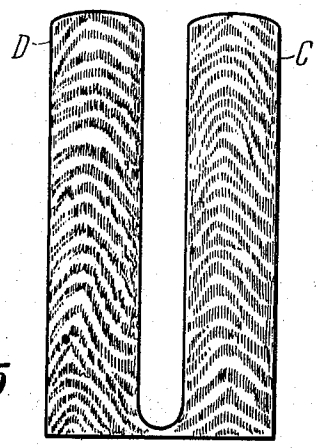


FIG.15

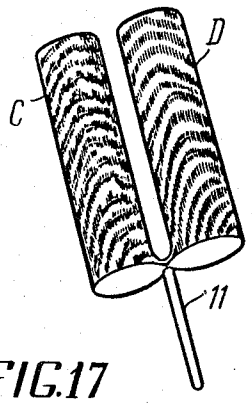


FIG.17

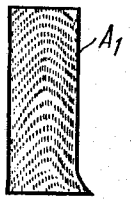


FIG.14

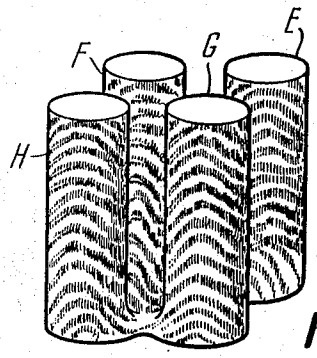


FIG.16

METHOD AND APPARATUS FOR MANUFACTURING MONOCRYSTALLINE ARTICLES

The invention relates to metallurgical production and more particularly to a method of manufacturing monocrystalline articles and castings.

The invention may be used in manufacturing ingots and articles of metals and alloys thereof with arbitrary or predetermined crystallographic orientation, such as blades for turbine engines, permanent magnets, etc.

Monocrystalline articles differ from conventional polycrystalline articles primarily by the absence of boundaries between differently and arbitrarily oriented crystals, said boundaries often representing a weak zone during the operation of articles, especially at elevated temperatures. In addition, since crystals exhibit anisotropy, that is, their properties, especially magnetic and mechanical ones, depend upon crystallographic orientation, optimum orientation of a crystal may be used when utilizing monocrystalline articles, said orientation imparting the most improved characteristics to the article under operating conditions. Studies show that the service life of monocrystalline blades in a turbine engine is about four times longer at maximum operating temperature and about eight to ten times longer at moderate temperatures as compared to that of polycrystalline blades, and the capacity of monocrystalline permanent magnets is about three to four times greater than that of the magnets having polycrystalline structure.

Known in the art is a method of manufacturing monocrystalline articles comprising the pouring of molten metal into a mould, the base of the mould being cooled, with subsequent crystallization proper by gradually cooling the mould from the bottom up after nucleation of many crystals formed as a result of the cooling.

In this prior art method a ceramic mould is used having a bottom comprising a water-cooled metallic plate, the mould being attached to said plate by means of a flange and bolts.

Molten metal is poured into the mould. In so doing, a plurality of small-size equiaxial crystals having an arbitrary crystallographic orientation are formed on the mould bottom as a result of abrupt supercooling of the melt, as it generally occurs during crystallization of metal poured into a cold mould adjacent the walls and the bottom thereof.

The concurrent growth results in the survival of only the most rapidly growing crystals, which have the direction of growth parallel with respect to the edge of a cubic crystal cell referred to as 001 in crystallography. These crystals are substantially parallel with each other and grow normally to the surface of the water-cooled plate. At some distance from the plate the vertical cavity of the mould changes into a horizontal cavity (construction), whereby the selection of these crystals which are adjacent to this transitory portion takes place. Columnar crystals are converted into plate crystals. Then, by using the next transistory horizontal cavity normal to the first one, one crystal adjacent to the transitory portion is withdrawn from this group of the plate crystals, and this crystal is introduced into the vertical cavity of a mould to form an article. Thus, a crystal seed having the crystallographic direction 001 is actually selected, and an article, such as a blade for a turbine engine, is grown from this crystal seed.

This method exhibits a number of disadvantages, one of which consists in that the articles can be produced only with one crystallographic orientation, namely 001. This excludes the possibility of obtaining articles having other crystallographic orientations, such as **112**, **111** which could be better than those of the **001** orientation in regard to a number of operational characteristics.

Furthermore, the entire system of transitory portions and cavities disposed under the article-forming cavity is lost as waste material, that is its purpose consists solely in the selection of one crystal to be introduced into the article-forming cavity of the mould. The same system of auxiliary cavities results in considerable distance between the article and the chill thereby hampering intensive cooling of the article, whereby its mechanical properties are impaired.

It is an object of the invention to provide a method which ensures the production of monocrystalline articles by growing each time only one crystal in a mould, the cavity of the mould following the article shape and having no system of auxiliary transitory portions.

It is another object of the invention to provide an apparatus for manufacturing monocrystalline articles having any desired crystallographic orientation of the crystal.

The invention consists in the provision of a method and apparatus for manufacturing monocrystalline articles, wherein a mould adapted to be poured with a melt of the article material and the conditions of cooling of this mould are such as to obtain an article grown directly from one crystal nucleus formed on the mould bottom, with the crystallographic orientation of the crystal being predetermined in conformity with the requirements of the article.

The above object is accomplished by the method comprising pouring of molten metal into a mould having a flat horizontally extending base, said base being cooled from the bottom, with subsequent crystallization proper by gradually cooling the mould from the bottom up after nucleation of a crystal formed as a result of cooling and its propagation over the perimeter of the mould.

According to the invention a monocrystalline article is obtained in a mould comprising two cavities: a top main cavity following the article shape, and an auxiliary bottom cavity adjacent thereto and made in the form of a downwardly enlarging truncated cone, said cone having a horizontally extending wedge-shaped projection at the lower-base thereof, a chill creating the conditions of the most abrupt supercooling at the point of the projection so as to form a sole natural crystal nucleus and to ensure its rapid propagation over the perimeter of the base.

Since the crystal is anisotropic, i.e., its properties in different directions depend upon the crystallographic orientation, then, in order to obtain an article with absolutely definite and repeated characteristics, it is necessary to manufacture it in a definite crystallographic orientation. For this purpose, an artificial seed is introduced into the place of formation of a natural seed.

The method according to the invention is carried out in an apparatus comprising a mould adapted to be poured with a melt of the article material, said mould

having a flat horizontally extending base and a chill arranged under the mould base in parallel therewith.

Artificial seeds may determine not only the axial orientation of an article but also orientation in the horizontal plane, which can affect the characteristics of an article in its operation.

According to the invention the mould comprises two cavities: a main top cavity following the article shape, and an auxiliary bottom cavity adjacent thereto and made in the form of a downwardly enlarging truncated cone, said cone having a horizontally extending wedge-shaped projection at the lower base thereof.

In order to achieve convenient accommodation of the article mould in a heated chamber and rational utilization of its volume, it is advantageous that the auxiliary bottom cavities of at least two moulds be connected with the points of their wedge-shaped projections to form a connection, with the point of this connection being located over the central part of the chill and representing the point of formation of a sole natural nucleus of a crystal forming at least two articles each having an identical crystallographic orientation.

The employment of the rods in the disclosed method is stipulated by the necessity of cooling the article while operating, e.g., a turbine engine blade wherein the cooling is effected through the internal space of the blade formed by a special fire-proof rod placed into the model of an article. Then, the mold is made according to the model of the article. After manufacturing the mold, the model is removed by dissolution or smelting, the rod remaining rigidly fixed in the mold by its one end. The other end of the rod being fitted is given certain freedom to ensure its movements under the effect of temperature.

Since the seed pocket is provided in the bottom of the mold and is protruded downward, and a crystal seed is rabbled in said pocket, and for giving birth to a crystal, the cooler should be brought into contact in its upper space with the bottom of the mold, said cooler is furnished with a seat to accommodate the seed pocket when the cooler is brought to the bottom of the mold.

It is advantageous that a mould for a large-size article, which will occupy the entire heated chamber, have two auxiliary cavities arranged under the main cavity, said cavities being connected at the point of their wedge-shaped projections, with the point of their connection being located over the central part of the chill.

According to one embodiment of the invention an artificial nucleus is introduced through a crystal seed at the point of formation of the natural crystal nucleus, said artificial nucleus allowing for obtaining a crystal having a crystallographic orientation of the article axis determined by the artificial nucleus.

According to another embodiment of the invention a crystal seed comprises a body of revolution cut from a crystal having a predetermined crystallographic orientation, the crystallographic plane of the crystal seed being set in parallel with the article axis by rotating said body.

Since the seed has a measurable length, it should be welded in its top part to attain necessary contact with the smelt delivered into the mold and is preserved in a solid state in the lower part.

Still another embodiment of the invention consists in that at the point of formation of the natural crystal nucleus the mould is provided with a seed pocket adapted to accommodate a crystal seed disposed normally to the mould base.

According to a further embodiment of the invention a unit for cooling the crystal seed is accommodated under the crystal seed in contact therewith to control melting of the top of the crystal seed.

Another embodiment of the invention permits obtaining hollow articles by placing a core into the mould, said core being removed upon completion of crystallization.

Where an artificial crystal nucleus is used, the apparatus according to the invention comprises disposed at the central part of the chill a recess for a seed pocket with a crystal seed and for a unit for cooling the crystal seed received in this recess during the upward movement of the chill.

The detailed description of the invention will now be made with reference to the accompanying drawings, in which:

FIG. 1 shows a diagrammatical generally longitudinal sectional view of the apparatus for manufacturing monocrystalline articles;

FIG. 2 is ditto, alternative embodiment;

FIG. 3 is a mould for manufacturing a monocrystalline ingot in longitudinal section;

FIG. 4 is a diagram of a unit consisting of two moulds;

FIG. 5 is a diagram of a unit consisting of six moulds for manufacturing monocrystalline blades for a turbine engine;

FIG. 6 is a diagrammatic view of a mould for manufacturing a large-size article;

FIG. 7 is a plan view of an auxiliary cavity of a mould for manufacturing a monocrystalline ingot;

FIG. 8 is an auxiliary cavity of a mould for manufacturing a monocrystalline blade;

FIG. 9 is ditto, alternative embodiment;

FIG. 10 is a turbine blade;

FIG. 11 is ditto, alternative embodiment;

FIG. 12 is a side view of the blade lock;

FIG. 13 is a side view of the blade airfoil;

FIG. 14 is a cylindrical monocrystalline ingot;

FIG. 15 shows cylindrical ingots made from one crystal nucleus in a unit consisting of two moulds;

FIG. 16 shows cylindrical ingots made from one crystal nucleus in a unit consisting of four moulds;

FIG. 17 shows two cylindrical monocrystalline ingots made from an artificial crystal nucleus introduced through a crystal seed;

FIG. 18 is ditto, with orientation in a stereographic triangle;

FIG. 19 shows orientation of ingots made in a unit consisting of two moulds, in a stereographic triangle;

FIG. 20 shows orientation of ingots made in a unit consisting of four moulds in stereographic triangle; and

FIG. 21 shows two cylindrical monocrystalline ingots with crystal seeds made in one unit therewith.

An apparatus for manufacturing monocrystalline articles comprises a mould 1 (FIG. 1) enclosed by a graphite heating element 2 mounted on power supply leads 3. The mould 1 comprises a main cavity A following the article shape, and an auxiliary cavity B adjacent thereto from the bottom. A chill 4 is arranged under the mould 1. The mould 1 together with the heating elements 2 and the chill 4 are placed in a vacuum chamber 5 having water-chilled walls. A vertical rod 6 adapted to reciprocate relative to the chamber 5 extends through the top cover of the chamber 5. The rod

is provided with an internal passage for cooling with water during the operation. A drive for the rod **6** comprises an electric motor with a reduction gear (not shown). Mounted at the end of the rod **6** inside the chamber **5** is a support member **7** adapted to fix the mould **1** thereto. Extending through the bottom of the chamber **5** is a vertical movable rod **8,** the chill **4** being supported at the upper end of this rod inside the chamber **5.** The rods **6** and **8** are coaxial. The chill **4** comprises a flat horizontally extending plate cooled with water fed through a passage which is made in the rod **8** and communicates with a passage extending in the body of the plate of the chill **4.** The rod **8** is also driven by means of an electric motor and a reduction gear (not shown). The mould **1** is suspended to the support member **7** by means of an adapter **9** functioning as a grip for holding the mould **1.** In order to obtain articles having a predetermined crystallographic orientation, a crystal seed is used. In this case the mould **1** (FIG. **2**) for the article is provided with a seed pocket **10** accommodating a crystal seed **11.**

Mounted under the crystal seed **11** in the seed pocket **10** is a nut **12,** a unit **13** for cooling the crystal seed **11** being fixed to said nut in contact with the lower end face of the crystal seed. The unit **13** for cooling the crystal seed **11** is adapted to remove heat from the crystal seed and to control melting of the top of the seed. In this case the chill **4** is provided at the central part thereof with a recess **14** accommodating the seed pocket **10** with the crystal seed **11** and the unit **13** for cooling the crystal seed **11.** The depth of the recess **14** is determined by the size of the crystal seed **11** and of the unit **13** which should be completely received in the recess **14** so that the chill **4** can contact the base of the mould **1** for conducting the crystallization process.

The unit **13** for cooling the crystal seed **11** comprises a metallic cylinder, such as a copper cylinder, disposed in a sleeve **15** movable along the generatric lines of the cylinder. Due to this embodiment the length of the unit **13** may be varied to adjust the distance between the base of the mould **1** and the chill **4.**

The mould **1** comprises two cavities: the main top **9** cavity A following the article shape, and the auxiliary bottom cavity B made in the form of a downwardly diverging truncated cone, said cone having a horizontally extending wedge-shaped projection at the lower base thereof. This projection is formed by the method of inventment pattern during the manufacture of the mould **1.** Accordingly, a fusible mass, such as a mixture of paraffine and stearine, or urea is poured into a metallic die having a cavity following the shape and size of the article to be produced. The resulting pattern is immersed into a dense binding mass, and then a layer of a finely divided granular material, such as electro corundum is spread onto this mass through a sieve, after which drying is effected. The immersion, spreading with granular material and drying operations are then repeated until eight to ten layers have been applied.

Then the pattern is melt out or dissolved, and the envelope is roasted. The resulting mould **1** should have a flat bottom of uniform thickness over the entire surface area. This is required to ensure constant heat conductance of the bottom over the entire surface thereof.

The crystal seed **11** comprises a body of revolution, such as a cylinder or a cone cut from a single-crystal having a predetermined crystallographic orientation. Therefore, the crystallographic orientation of the crystal seed **11** is also predetermined. By rotating the crystal seed **11** about its axis the crystallographic plane thereof can be set in parallel or at a predetermined angle with respect to the article plane.

The capacity of the chill **4** is selected depending upon the time necessary to cool the base of the mould **1** and to supercool a melt of the material filling up the auxiliary cavity B thereof. If the chill **4** is too powerful, it may not only result in cooling of the base of the mould **1,** but also of the zones of the peripheral surface thereof adjacent to the chill, which is not desirable. With low capacity of the chill **4** the process of supercooling of a melt of the material in the auxiliary cavity B of the mould **1** and the nucleation of a crystal will be too long, which may disturb uniformity of the article single-crystal as to crystallographic orientation at the beginning of the growing thereof.

In order to obtain hollow articles, such as the blades for a turbine engine having a cavity for cooling, a core **16** is placed into the mould **1,** the core following the shape of the internal cavity of the article.

The disclosed method enables also to manufacture hollow articles, e.g., a turbine blade with air cooling, shown in FIG. **12** from the side of the lock and in FIG. **13** from the side of the upper bandage shelf.

The important feature of the method of manufacturing monocrystalline articles consists in that a layer of melt poured into the mould **1** will be the thinnest in the point of the wedge-shaped projection of the auxiliary cavity thereof. In addition, the heat conductance of the melt over the central part of the auxiliary cavity is substantially higher than the heat conductance of the material of the mould **1** over the thin layer of the melt at the point of the wedge-shaped projection.

Due to this fact, abrupt supercooling is carried out under the influence of the chill **4** in the wedge-shaped projection, this supercooling gradually diminishing along the perimeter of the base thereby contributing to the creation of a radial temperature gradient directed towards the point thereof. All the above reasons contribute to the nucleation of a crystal at the point of the wedge-shaped projection of the mould **1** and to its rapid propagation over the perimeter of the base, whereby the nucleation of parasitic crystals in this zone is eliminated.

FIG. **21** shows two monocrystalline ingots (C) and (D) produced in one unit with monocrystalline seeds (II). To manufacture such a unit, a model is made up of two ingots with the models of seeds being connected to them on a common base. The model assembled in such a manner is fed to produce the mold.

The apparatus functions as follows.

The mould **1** accommodated in a vacuum chamber **5** is heated by means of the heating elements **2** at a temperature above that corresponding to the beginning of the melt crystallization.

Then a metal melted in a separate furnace is poured into the mould **1.** The temperature of the melt is checked by means of an immersion thermocouple immediately beforehand. The temperature of the melt at the instant of its pouring into the mould **1** should be about 100°– **120°C** higher than the temperature corresponding to the beginning of crystallization, but somewhat lower than the temperature of the mould **1** so that after the pouring in the zone adjacent to the base the temperature should be about 30°– 40°C lower than the temperature of the walls of the mould **1** at the same al-

titude. When too overheated, the metal will require other cooling conditions, which may result in the formation of parasitic crystals adjacent the mould base.

During the heating of the mould 1 the chill 4 is spaced at such distance from the base thereof, that its cooling action upon the mould is practically eliminated.

FIG. 6 shows a large-size article which, due to its large dimensions, can be manufactured only in the copy. In this case, two auxiliary spaces are arranged below the main space of the article, said two spaces being connected by the points of the wedge-shaped projections, and the place of their connection being disposed above the central part of the cooler. FIG. 7 shows a plan view of the lower space of the article produced in the mold whose drawing is given in FIG. 3. Symbol A denotes the upper base of the article's space, and symbol B the lower base.

FIGS. 8 and 9 show a plan view of the lower space of the mold to produce monocrystalline blades depicted in FIGS. 10 and 11 respectively.

Upon pouring of metal into the mould 1 it is allowed to stay so during a time necessary for achieving the correspondence between the temperature of the melt and the mould 1.

By the end of the curing period the temperature of the melt immediately adjacent the base of the mould 1 should about by 30°– 40°C higher than the temperature corresponding to the beginning of crystallization.

In order to effect the nucleation of a crystal the chill 4 mounted on the movable rod 8 is fed towards the base of the mould 1 at a speed ensuring its contact with the mould 1 at the instant, when the temperature of the melt adjacent the base of the mould will become about 30°– 40°C lower then the temperature corresponding to the beginning of crystallization. In this example the process continues for 10 – 12 minutes.

At the instant of the contact between the chill 4 and the base of the mould 1 the melt in the wedge-shaped projection of the auxiliary cavity thereof and slightly higher has been already solidified. Thus, during the period of gradual movement of the chill 4 towards the base of the mould 1 a supercooling of the melt was created in the point of the wedge-shaped projection thereof and the formation of a sole crystal nucleus took place which subsequently propagated over the perimeter of the base of the mould 1.

Upon effecting the contact between the chill 4 and the mould 1 the latter is disconnected from the support member 7, and the mould 1 on the chill 4 is gradually withdrawn by means of the rod 8 downwards from the zone of location of the heaters 2. The speed of movement of the chill 4 with the mould 1 supported thereon is determined by the article shape.

In order to avoid the formation of parasitic crystals on the article surface, the temperature of the walls of the mould 1 should be maintained at a level higher than the temperature corresponding to the beginning of solidification of the metal, which is achieved by maintaining a temperature gradient in the metal, in this example of about 10°/cm.

The crystal growth is controlled in such a manner that the melt-crystal inter-face that is the growth front be maintained at one and the same level relative to the heating element 2 of the mould 1. This control is effected by means of a thermocouple tracing the location of the growth front, and the readings of the thermocouple must be constant until the end of the lowering of the mould 1 into the cold zone.

In this case, where hollow articles are to be produced, the core 16 (FIGS. 12 and 13) placed into the mould 1 does not introduce any changes into the formation and growth of the crystal nucleus. Thus, the crystal while propagating over the surface of the base of the mould 1, "flows" round the core 16 from all sides. Upon the manufacturing of the article the core 16 is removed by the hydrodynamic or any other appropriate method.

If the crystal seed 11 is used for manufacturing an article, it is placed into the seed pocket 10. The seed pocket 10 and the unit 13 for cooling the crystal seed 11 are being introduced into the recess 14 at the central part of the chill 4 during the movement of the chill 4. Thus, the movable sleeve 15 moves upwards into alignment with the main cylinder of the unit 13 thereby reducing the length thereof. At the instant of contact of the chill 4 with the base of the mould 1 the seed pocket 10 and the unit 13 are completely received in the seat 14 and do not interfere with this engagement.

Further process of the manufacturing of the article is performed similarly to the above-described embodiment.

In order to ensure more rational utilization of the volume of the vacuum chamber 5, at least two articles are generally made therein. In this case the auxiliary cavities of at least two moulds 1 are connected with the points of their wedge-shaped projections to form a unit. The point of connection is located over the central and the coldest part of the cooler 4. The moulds 1 are arranged symmetrically with respect to each other. Four, six and more moulds may be connected in the similar manner. In this case the nucleation of a crystal takes place at the point of connection of the wedge-shaped projections, and the process continues similarly to the case, where a single article is produced.

Similar method may be used for manufacturing crystal seeds having a predetermined crystallographic orientation determined by an artificial crystal nucleus (FIG. 21).

FIG. 15 shows cylindrical monocrystalline ingots obtained by the method according to the invention in a unit consisting of two moulds.

FIGS. 19 and 20 illustrate the results of determination of the crystallographic orientation of the ingots obtained in a unit consisting of two moulds 1 and in a unit consisting of four moulds 1 respectively by the Laue method. As it will be apparent from the both stereographic triangles, differences in orientation do not exceed two degrees in both cases.

FIGS. 10 and 11 show turbine blades made by the method according to the invention. FIG. 17 shows two cylindrical ingots C and D with a common base, said ingots having a crystallographic orientation predetermined by the crystal seed 11.

FIG. 18 shows the result of determination of orientation of the both ingots as compared to the crystallographic orientation of the crystal seed 11. The results are consistent within the range of two degrees.

Table 1 shows the results of determination of stress-rupture results obtained during the tests of samples of a length of 38 mm and a diameter of 3 mm made of a highly refractory nickel-based alloy at 980°C under a load of 21 kg/mm². Monocrystalline samples K, L, M, N and polycrystalline samples O, P, Q, R were tested

after heat treatment, which consisted in their exposure at 1220°C for four hours, cooling in the air and subseqauent ageing at 870°C for 32 hours.

Table 1

Samples	Rupture time (h)	Elongation (%)	Reduction of area %	Test type
K	283	20.0	30.0	Stress-rupture
L	141.5	20.0	30.0	do.
M	282.5	24.8	31.4	Creep rupture
N	321.0	25.5	31.5	do.
0	16.0	1.0	2.0	Stress-rupture
P	30.5	3.5	6.5	
Q	29.0	2.0	6.5	
R	11.5	3.5	6.5	

As it will be apparent from Table 1, the results of the tests of the monocrystalline samples K, L, M, N are considerably better than those obtained for the polycrystalline samples O, P, Q, R, both in regard to time to rupture, and elongation and reduction, which in the case of monocrystalline turbine blades corresponds to an increase in the service life of a turbine engine by 4 – 6 times.

What is claimed is:

1. A method of manufacturing monocrystalline articles comprising the steps of pouring molten metal into a mould comprising a main top cavity following the article shape and an auxiliary bottom cavity adjacent thereto and made in the form of a downwardly enlarging truncated cone, said cone having a horizontally extending wedge-shaped projection at the lower base thereof, which defines the base of said mould; cooling the base of said mould by means for cooling thereof so as to create the most abrupt supercooling of the melt at the point of said wedge-shaped projection, to form at this point a sole natural crystal seed and to ensure its rapid propagation over the entire perimeter of said base; and subsequent gradual cooling of said mould from the bottom up to effect the crystallization proper.

2. An apparatus for manufacturing monocrystalline articles comprising a mould adapted to be poured with a molten article material; said mould having a flat horizontally extending base; said mould having a main cavity following the article shape and an auxiliary bottom cavity adjacent thereto and made in the form of a downwardly enlarging truncated cone, said cone having a horizontally extending wedge-shaped projection at the lower base thereof; a chill arranged under the base of said mould in parallel therewith.

3. An apparatus according to claim **2,** wherein the auxiliary cavities of at least two moulds are connected at the points of their wedge-shaped projections to form a unit, with the point of their connection being located over the central part of the chill and representing the point of formation of a sole natural crystal nucleus forming at least two articles having an identical crystallographic orientation.

4. An apparatus according to claim **2,** wherein the mould for a large-size article has two auxiliary cavities disposed under the main cavity and connected at the points of their wedge-shaped projections, the point of their connection being located over the central part of the chill.

5. An apparatus according to claim **2,** wherein an artificial crystal nucleus is introduced at the point of formation of the natural crystal nucleus through a crystal seed, said artificial nucleus allowing for obtaining a crystal with the crystallographic orientation of the article axis predetermined by the artificial crystal nucleus.

6. An apparatus according to claim **5,** wherein the crystal seed comprises a body of revolution cut from a crystal having a predetermined crystallographic orientation, the crystallographic plane of the crystal seed being set in parallel with the article planeby rotating said body.

7. An apparatus according to claim **5,** wherein a unit for cooling the crystal seed is arranged under the crystal seed and in contact therewith, said unit being adapted to control melting of the top of the crystal seed.

8. An apparatus according to claim **5,** wherein a mould is provided with a seed pocket disposed under the point of formation of the natural crystal nucleus and adapted to accommodate the crystal seed, said pocket being arranged normally to the base of the mould.

9. An apparatus according to claim **2,** wherein a core is placed into the mould for obtaining a hollow article, said core being removed upon completion of crystallization.

10. An apparatus according to claim **8,** wherein the chill is provided with a recess at the central part thereof to accommodate the seed pocket with the crystal seed and the unit for cooling the crystal seed.

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