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(54) METHOD AND APPARATUS FOR PRODUCING DIRECTIONALLY SOLIDIFIED CASTINGS

VERFAHREN UND VORRICHTUNG ZUM HERSTELLEN GERICHTET ERSTARRTER GUSS-STÜCKE

PROCEDE ET APPAREIL PERMETTANT DE PRODUIRE DES MOULAGES A SOLIDIFICATION ORIENTEE

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to metal casting and can be used in producing castings with directional and single crystal structure. In particular the invention relates to a metal casting apparatus with a water-cooled tank having a truncated cone shape.

BACKGROUND OF THE INVENTION

[0002] An apparatus for directional solidification generally comprises a vacuum chamber inside which there are disposed a mold heating zone, a baffle system, a water-cooled chill plate usually made of copper, an induction furnace, and a thermocouple system that automatically controlls and maintains the temperature in a cooling zone and in a heating zone within the furnace. Such features are disclosed in U.S. Patent Nos 3680625, 4804311, and 4412577.

[0003] Also known in the art is an apparatus for directional solidification, in which the cooling zone is a liquid cooling bath with a material that melts easily to serve the role of the cooling medium. The liquid metal bath is disclosed in U.S. Patent Nos 3763926 and 3915761, and Russian Federation Patent No 2010672.

[0004] Apparatuses in which both types of the above mentioned assemblies are combined (i.e., the copper chill plate and the liquid metal cooling bath) are also known. But those apparatuses comprise two actuators for vertical transportation of a mold with a metal casting. These actuators are disposed above and beneath the vacuum chamber housing. For that reason the dimensions of the apparatuses are enlarged and the service of the installations become complicated while the reliability of the apparatuses is decreased (see U.S. Patent 5197531, and the publication Singer R.F. "Directional and Single Crystal Solidification Using LMC").

[0005] The closest prior art to the present invention is an apparatus disclosed in French Patent Application 2604378, being accepted as a prototype. This prototype apparatus comprises a vacuum chamber with a heating member inside where there is disposed a ceramic mold fixed on a water-cooled metallic plate which is moved up and down with the help of a rod and of an actuator for vertical transportation. A horizontal baffle separates a heating zone and a cooling zone. In the cooling zone, concentrically with the chill plate, there is disposed an additional circular water-cooled cavity with the inner diameter exceeding the mold's maximal size. Below the cavity there is disposed a container which is utilized for capturing the poured casting metal in the event of mold breakage.

[0006] The above apparatuses, including the prototype, can function only when they comprise a crystallizer. It is impossible to use such installation for directional solidification processing with a liquid metal coolant and it is difficult to utilize the expensive alloys used in directional solidification castings in the event of mold breakage. Thus there is a need for a casting apparatus that provides a means that efficiently cools the molten cast alloy while protecting the equipment from damage in the event that the ceramic mold breaks while containing the molten cast alloy material.

SUMMARY OF THE INVENTION

[0007] The technical aim of this invention is to produce castings having the directional and single crystal structure by the method of radiation cooling without using the above-mentioned crystallizer. Another aim of the invention is to be able to reconstruct easily the invented apparatus for both radiation crystallization processing and liquid metal cooling crystallization processing. The inventive apparatus also increases the reliability and economic profit due to the apparatus' performance.

[0008] To achieve said aim the invention comprises an apparatus in accordance with claim 1 hereof and a method in accordance with claim 9. In one embodiment, the inventive apparatus comprises a vacuum chamber inside which there is disposed an induction melting furnace, a mold preheating furnace with a ceramic mold, a drive assembly for mold transportation and a water-cooled tank. The drive assembly comprises a rod on which the mold is fixed with the help of a hanger and a regulating actuator for vertical movement being positioned above the vacuum chamber. The water-cooled tank is shaped as a truncated cone. Its upper portion is opened towards the heating zone, and its bottom portion has a smaller base than the upper portion. A baffle separates the heating zone inside the induction furnace from the cooling zone; said baffle moves in a horizontal plane and closely adjoins the mold during the solidification process. It consists of the segments or sectors (not less than 2 from each side).

BRIEF DESCRIPTION OF THE DRAWING

[0009]

Fig.1 shows a schematic drawing of the apparatus where I is the ceramic mold, 2 is the hanger to fix the mold to the drive assembly, 3 is the rod, 4 is the heater of the mold preheating furnace, 5 is the heat baffle, 6 is the water cooled tank, 7 is the molten superalloy, and 8 is the starting zone with a seed.

DESCRIPTION OF THE INVENTION

[0010] The apparatus performs as follows: the mold (1) is disposed on the hanger (2) and is fixed on the movable rod (3). The hanger (2), the movable rod (3), and the regulating actuator comprise the drive assembly (14). The mold (1) is placed into the mold preheater furnace (9) with the help of the actuator while regulating

the mold position relative to the heater (4). The heat baffle (5) is disposed under the heating zone (10). The top butt end of the water-cooled tank (6) adjoins the baffle's (5) lower surface and is positioned coaxially with the heater (4) and (11). The vacuum chamber (12) is evacuated to 1 x 10^{-3} mm m.c. The mold preheating furnace (9) is switched on. Upon reaching the mold temperature of 100-150 °C higher than the liquidus temperature of the alloy being cast, the induction furnace's heater (11) is switched on, the alloy (7) being cast melts and is poured into the heated ceramic mold at the predetermined temperature. After that, the actuator for vertical transportation lowers the mold from the heating zone (10) into the cooling zone (13) at the required rate. Solidification of the molten cast alloy occurs by radiation onto the cold walls of the water-cooled tank. Due to this fact it becomes possible to produce large sized castings with directional and single crystal microstructure. Large size castings can include blades, nozzles, buckets, airfoils, and the like, that are used both in aircraft and land-based turbine engines. The castings are often greater than 30 inches in overall height.

[0011] Once the mold with the casting alloy has been lowered along its complete height into the cooling zone, the heater (4 and 11) is switched off. When the temperature is decreased to 300-400 °C, the mold with the solidified casting alloy is extracted from the installation which has been previously decompressed. Then the process is repeated for the next mold.

[0012] In another aspect of this invention, in order to produce blades having single crystal structure with desired orientation, a single crystal seed with proper orientation is positioned into the top of the starting zone (8) of the ceramic mold before it is disposed in the vacuum chamber. Then the mold position is strictly fixed relative to the heater. In such event the seed and the solidified portion of the starting zone serve as a cooling medium, and further solidification of the melt is caused by radiation cooling in the water-cooled tank as stated above. The use of the water-cooled tank instead of a chill plate allows the same or better working efficiency of said tank than that of a chill plate or of the prototype circular water-cooled cavity. At the same time the water-cooled tank of this invention does not require the use of a complex drive assembly with airtight seals.

[0013] As stated above, the heat baffle (5) is used for raising the axial temperature gradient at the solidification front. Said baffle moves in a horizontal plane, closely adjoins the ceramic mold according to its geometry during the solidification process and consists of the segments or sectors (not less than 2 from each side).

[0014] In the inventive apparatus the water-cooled tank may be made of stainless steel and contain a double layer wall surrounding the perimeter of the tank. A vacuum atmosphere is created in the tank to further aid in the cooling of the cast parts. The tank may also effectively function as a mold catch basin in the event of mold breakage, and the expensive, poured casting alloy may be easily removed from the tapered tank and be remelted.

[0015] The apparatus of this invention allows one to produce high quality castings having the directional and single crystal structure, including the large sized castings used in the land based turbine industry, by the method of radiation cooling without using the crystallizers of the prior art. The invention also gives the possibility to reconstruct easily the disclosed apparatus for liquid metal cooling crystallization processing, to use successively the invented water-cooled tank as a mold catch basin in the event of mold breakage, and to increase the reliability and economic profitability of the apparatus' performance.

Claims

1. An apparatus for producing castings, with directional and single crystal structure, the apparatus comprising a vacuum chamber (12) inside which there is positioned an induction melting furnace (15), and a mold preheating furnace (9), a ceramic mold (1) being fixed to a transportation drive assembly (14) comprising a rod (3) and an actuator (14) for vertical movement, cooling means, a baffle (5) separating a heating zone (10) and a water-cooled tank (6) having a closed bottom portion (16) and an upper portion (17) opened towards the heating zone (10), **characterised in that** the cooling means consists of said water-cooled tank (6) and the actuator is positioned above the vacuum chamber.

2. The apparatus of claim 1 **characterized in that** the water-cooled tank (6) is shaped as a truncated cone with its bottom portion (16) having a smaller base than the upper portion (17) of the tank (6).

3. The apparatus of claim 1 **characterized in that** a baffle (5) articulates in a horizontal plane and consists of at least two sectors or segments, closely adjoining the ceramic mold (1) during a solidification process.

4. The apparatus of claim 1 where the drive assembly (14) further comprises a mold hanger (2).

5. The apparatus of claim 1 where said water-cooled tank (6) can be used as a mold catch basin.

6. The apparatus of claim 1 where said mold (1) contains a starter cavity (8) for a crystal having a defined crystal orientation.

7. The apparatus of claim 1 where the water-cooled tank (6) has a double wall.

8. The apparatus of claim 1 where the water-cooled

tank (6) is made of stainless steel.

9. A method of making a directional or single crystal alloy structure comprising the steps of: placing a mold (1) in a mold preheating furnace (9) relative to a heater (4), the mold being fixed to a transportation drive assembly comprising a rod (3) and an actuator (14) for vertical movement positioned above the vacuum chamber; heating the mold (1) to a temperature of about 100 to 150 °C above the liquidus temperature of a casting alloy; melting the casting alloy; pouring the molten alloy (7) into the heated mold (1); lowering the mold (1) with the molten alloy at a required rate from a heating zone (10) into a cooling zone (13) consisting of a water-cooled tank (6) comprising a closed bottom portion and an open upper portion with water-cooled walls extending therebetween; and solidifying the molten alloy by radiation onto the water-cooled walls of the tank (6).

10. The method of claim 9 where the mold (1) passes through a baffle (5) located between the heating zone (10) and the cooling zone (13).

Patentansprüche

1. Einrichtung zum Erzeugen von Gussstücken mit gerichteter und einkristalliner Struktur, wobei die Einrichtung eine Vakuumkammer (12), in der ein Induktionsschmelzofen (15) und ein Formvorheizofen (9) angeordnet sind, eine Keramikform (1), die an einer Transport-Antriebsvorrichtung (14) befestigt ist, die eine Stange (3) und ein Stellglied (14) für Vertikalbewegung aufweist, eine Kühlvorrichtung, eine Leitanordnung (5), die eine Heizzone (10) und einen wassergekühlten Tank (6) trennt, der einen geschlossenen Bodenabschnitt (16) und einen oberen Abschnitt (17) aufweist, der in Richtung auf die Heizzone (10) geöffnet ist, **dadurch gekennzeichnet, dass** die Kühlvorrichtung aus dem wassergekühlten Tank (6) besteht und das Stellglied über der Vakuumkammer angeordnet ist.

2. Einrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** der wassergekühlte Tank (6) wie ein stumpfer Kegel geformt ist, wobei sein unterer Abschnitt (16) eine kleinere Basis hat als der obere Abschnitt (17) des Tanks (6).

3. Einrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** eine Leitanordnung (5) in einer horizontalen Ebene angelenkt ist und aus wenigstens zwei Sektoren oder Segmenten besteht, die während eines Erstarrungsprozesses eng an der Keramikform (1) angrenzen.

4. Einrichtung nach Anspruch 1, wobei die Antriebsanordnung (14) ferner einen Formaufhänger (2) aufweist.

5. Einrichtung nach Anspruch 1, wobei der wassergekühlte Tank (6) als eine Formauffangbecken benutzt werden kann.

6. Einrichtung nach Anspruch 1, wobei die Form (1) eine Starterkammer (8) für einen Kristall mit einer definierten Kristallorientierung enthält.

7. Einrichtung nach Anspruch 1, wobei der wassergekühlte Tank (6) eine Doppelwand aufweist.

8. Einrichtung nach Anspruch 1, wobei der wassergekühlte Tank (6) aus rostfreiem Stahl hergestellt ist.

9. Verfahren zum Herstellen einer direktionalen oder einkristallinen Legierungsstruktur enthaltend die Schritte: Anordnen einer Form (1) in einem Formvorheizofen (9) relativ zu einer Heizeinrichtung (4), wobei die Form an einer Transport-Antriebsvorrichtung befestigt wird, die eine Stange (3) und ein Stellglied (14) für Vertikalbewegung aufweist, die sich über der Vakuumkammer befindet; Erhitzen der Form (1) auf eine Temperatur von etwa 100 bis 150°C über der Liquidus-Temperatur einer Giesslegierung; Schmelzen der Giesslegierung; Giessen der geschmolzenen Legierung (7) in die erhitzte Form (1); Absenken der Form (1) mit der geschmolzenen Legierung bei einer erforderlichen Rate von einer Heizzone (10) in eine Kühlzone (13), die aus einem wassergekühlten Tank (6) besteht, der einen geschlossenen Bodenabschnitt und einen offenen oberen Abschnitt aufweist, wobei sich dazwischen wassergekühlte Wände erstrecken; und Erstarren der geschmolzenen Legierung durch Strahlung auf die wassergekühlten Wände des Tanks (6).

10. Verfahren nach Anspruch 9, wobei die Form (1) durch eine Leitanordnung (5) hindurchtritt, die zwischen der Heizzone (10) und der Kühlzone (13) angeordnet ist.

Revendications

1. Appareil servant à produire des pièces moulées à structure directionnelle et monocristalline, l'appareil comprenant une chambre à vide (12) dans laquelle est positionné un four de fusion à induction (15), et un four de préchauffage (9) de moule, un moule en céramique (1) étant fixé à un ensemble d'entraînement de transport (14) comprenant une tige (3) et un actionneur (14) pour le mouvement vertical, un moyen de refroidissement, un écran (5) séparant une zone de chauffage (10) et un réservoir (6) refroidi par eau ayant une partie inférieure fermée

(16) et une partie supérieure (17) ouverte vers la zone de chauffage (10), **caractérisé en ce que** le moyen de refroidissement est constitué par ledit réservoir (6) refroidi par eau et l'actionneur est positionné au-dessus de la chambre à vide.

2. Appareil selon la revendication 1, **caractérisé en ce que** le réservoir (6) refroidi par eau a une forme de cône tronqué, dont la partie inférieure (16) a une base plus petite que la partie supérieure (17) du réservoir (6).

3. Appareil selon la revendication 1, **caractérisé en ce qu'**un écran (5) est articulé dans un plan horizontal et est constitué d'au moins deux secteurs ou segments, qui sont étroitement contigus au moule en céramique (1) pendant un processus de solidification.

4. Appareil selon la revendication 1, dans lequel l'ensemble d'entraînement (14) comprend en outre un dispositif de suspension (2) de moule.

5. Appareil selon la revendication 1, dans lequel ledit réservoir (6) refroidi par eau peut être utilisé comme bassin épurateur de moule.

6. Appareil selon la revendication 1, dans lequel ledit moule (1) contient une cavité de démarrage (8) pour un cristal ayant une orientation cristalline définie.

7. Appareil selon la revendication 1, dans lequel le réservoir (6) refroidi par eau a une double paroi.

8. Appareil selon la revendication 1, dans lequel le réservoir (6) refroidi par eau est en acier inoxydable.

9. Procédé de fabrication d'une structure d'alliage directionnel ou monocristallin, comprenant les étapes consistant à : placer un moule (1) dans un four de préchauffage (9) de moule par rapport à un dispositif de chauffage (4), le moule étant fixé à un ensemble d'entraînement de transport comprenant une tige (3) et un actionneur (14) pour le mouvement vertical positionné au-dessus de la chambre à vide, faire chauffer le moule (1) à une température d'environ 100 à 150 °C au-dessus de la température de liquidus d'un alliage de moulage, faire fondre l'alliage de moulage, verser l'alliage fondu (7) dans le moule chauffé (1), abaisser le moule (1) avec l'alliage fondu à une vitesse requise d'une zone de chauffage (10) à une zone de refroidissement (13) constituée d'un réservoir (6) refroidi par eau comprenant une partie inférieure fermée et une partie supérieure ouverte avec des parois refroidies par eau s'étendant entre elles, et faire solidifier l'alliage fondu en le répandant sur les parois refroidies par eau du réservoir (6).

10. Procédé selon la revendication 9, dans lequel le moule (1) passe à travers un écran (5) situé entre la zone de chauffage (10) et la zone de refroidissement (13).

FIG.1

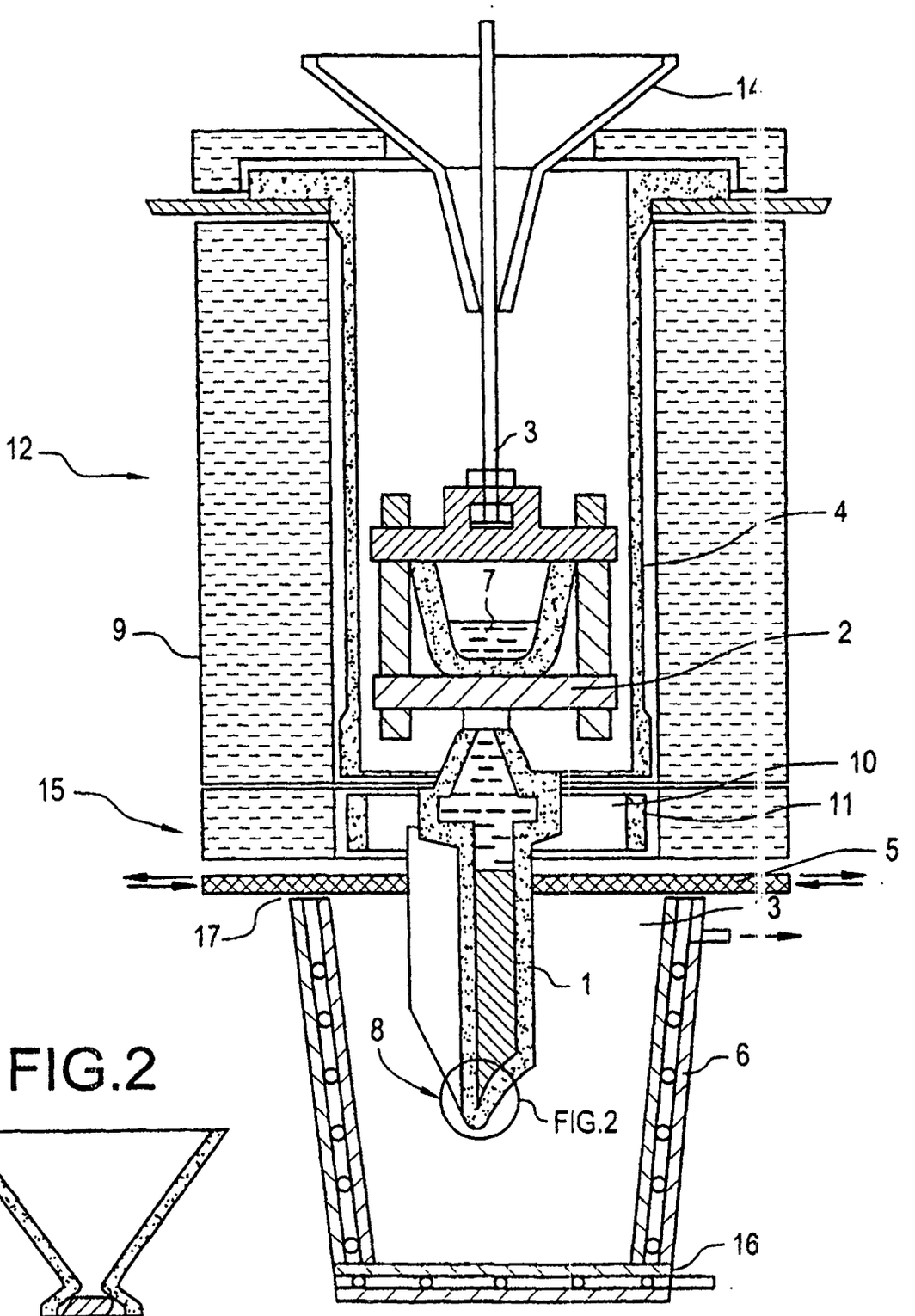

FIG.2