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(54) **INVESTMENT CASTING**

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• **Derwent's abstract, no. 92-70967/09, week 9209;
& SU,A,1637949, (Fershtater I B), 30-03-1991**

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Description

[0001] This invention relates to the casting of articles of molten metal and is particularly concerned with casting by the so-called investment or lost wax process. For such casting a very accurate model of the required product is produced in wax. A ceramic shell is then formed around the wax by applying successive coats of ceramic slurry and stucco. In this operation, the wax is dipped into a tank of slurry; on removal, excess slurry adhering to the wax model is drained off and dry granular ceramic stucco is applied to the surface either by raining it over the model, or by immersing the model in a fluidised bed containing the stucco. At this stage the first coating must be dried before the next coating can be applied. Further coats are applied in turn by the same process of dip, stucco and dry until the desired shell thickness is achieved. After reaching the required shell thickness, the mould must be further dried to remove residual moisture, after which it can be "dewaxed". In this step the wax model is removed from within the shell either by melting using superheated steam in an autoclave or by flash-firing the shell in a high temperature oven. Where an autoclave is used to remove the wax, the shell must subsequently be heated in a firing furnace at temperatures above 1000°C both to remove any traces of residual wax and to create a strong ceramic bond in the shell material. The resultant shell is then cooled to room temperature, repaired and cleaned of any internal debris, after which it is heated for several hours in a pre-heat furnace before being taken to a casting furnace or casting station to be filled with metal while at high temperature. Pre-heating is necessary to avoid thermal shock and to ensure that the mould fills completely, especially in thin sections. In many foundries, the same furnace is used for all firing and pre-heating operations which reduces capital investment but leads to logistical and productivity constraints.

[0002] Investment casting offers a manufacturing process capable of producing components of high definition, good dimensional accuracy and excellent surface finish. Its drawbacks, however are that it is limited in the size of components which can be cast and it is expensive to operate. One problem is caused by the fact that wax expands on heating and this can cause the surrounding ceramic shell to crack. It is one object of this invention to address these drawbacks by providing a casting process capable of delivering the benefits of investment casting but which is applicable over a greater size range and is cheaper to operate.

[0003] Much of the expense in investment casting is associated with the shelling operation and with the need to pre-heat the mould, these two things being intrinsically linked.

[0004] EP-A- 474 078 discloses an investment casting method using vacuum for filling the mould formed by a ceramic shell, which, apart from step 8) of claim 8, namely applying a vacuum to the granular filler sur-

rounding the shell, comprises all the steps mentioned in claim 8. At least the initial slurry used for coating the wax pattern is water based. The thickness of the thin-walled shell mould produced by the coating is about 2.5 mm. The temperature of firing and steam treatment in an autoclave to remove the wax is 135-176°C; a further firing treatment in order to improve gas permeability is not necessary, cf. such a step missing in the claims of the EP-A, but is mentioned taking place at 985°C in the description of the EP-A. The shell mould is placed in a box within loose particulate refractory media which are densified by vibration. A vacuum is not applied to the particulate refractory media but to the interior of the shell before and during the metal pouring step.

[0005] US-A-3 933 190 discloses investment casting of turbine blades from Ni- or Co-based superalloys.

[0006] In one aspect the invention provides a method of casting an article of molten metal, the method comprising casting the liquid metal into a supported thin ceramic shell having a smooth surface and which has not been pre-heated before ingress of the liquid metal and including the preliminary step of supporting the shell in a bed of compacted granular material and applying a vacuum to the compact granular material while the liquid metal is being cast into the shell whereby to draw all the metal into the shell.

[0007] A mould which is cast hot must be strong enough to withstand being handled at high temperature and also to avoid breakout during pouring. This is achieved by building up a substantial thickness of shell consisting of as many as 15 dip coats. In the present invention the mould is cold at the point when the molten metal is poured into it and it is supported in a bed of loose sand compacted to a high bulk density. In this process it is normal to apply only 5 to 7 coats depending on the size and geometry of the casting being produced leading to very significant savings in moulding materials, mould manufacturing lead time, work in progress and waste disposal costs. There are also environmental benefits in terms of raw materials usage reduction, waste stream reduction and, because the shell system used is water based, a complete elimination of the VOC volatile organic compound (VOC) emissions which occur when using alcohol based shell systems.

[0008] Further savings are made on casting. Because in this process moulds are cast cold, it is possible to cast several components together from a single large charge of metal. (Pre-heated, investment cast moulds are usually cast individually, each mould requiring a small, single billet of metal to be melted and poured, which is time consuming and costly.)

[0009] These two areas of cost saving, along with the energy saving gained through not having to heat up the mould immediately prior to casting, reduce the cost of producing castings to an extent which makes the process economically more viable for automotive and general commercial casting applications.

[0010] The ceramic shell is supported in a bed of gran-

ular material, for example, sand, while the molten metal is being cast into the shell. It is also preferred that the bed of granular material be at or near ambient temperature. The sand is compacted, preferably by vibration, before pouring and it is further compacted by applying a vacuum while the metal is being poured. The vibration is preferably of high frequency and low amplitude, typically 40 - 50 Hz and 0.045 mm RMS (root mean square) to optimise compaction of the backing material and to provide acceptable support for the mould.

[0011] The thickness of the ceramic shell is typically around 3 mm, i.e. relatively thin compared to most investment casting shells and is made by applying a relatively small number of slurry and stucco coat; each coat being dried before the next is applied. For most castings only five coats need to be applied to provide the necessary shell thickness.

[0012] The ceramic slurries used to form the coatings which make up the shell mould are preferably water-based. Suitable materials for use in these slurries include, but are not restricted to, zircon, silica, alumina and the alumino-silicate group of materials.

[0013] In one specific aspect the invention provides a method of casting an article of molten metal, the method comprising the steps of:

- 1) forming a pattern of the component(s) to be cast and the associated runner system from wax;
- 2) dipping the wax pattern into a tank of ceramic slurry comprising a refractory filler and a water based binder to form a coating on the pattern;
- 3) draining the excess slurry and applying refractory granules to the coating to form a stucco layer thereon and then allowing the coating to dry;
- 4) repeating steps (2) and (3) to form a coating about 3 mm thick;
- 5) removing the wax and allowing the resultant shell to cool to room temperature;
- 6) placing the shell in a mould box and surrounding it with granular filler;
- 7) vibrating the box to compact the filler to a high bulk density;
- 8) applying a vacuum to the granular filler;
- 9) pouring molten metal into the shell while mounting the vacuum;
- 10) removing the vacuum, allowing the casting to cool and then separating it from the filler; and
- 11) removing the shell to provide a casting having

a substantially smooth external surface.

[0014] The casting method is applicable to a wide range of alloys including iron, steel, aluminium, cobalt/chrome and nickel based superalloys.

[0015] Under typical investment coating conditions a reduction in pre-heating temperature results in a situation where the metal being cast freezes before it can completely fill all of the mould where two or more streams of molten metal fail to merge completely before freezing, leaving a discernible boundary between them in the solidified casting. The present method is much less prone to such defects because the vacuum which is applied to the thin shell draws the metal into the mould, encouraging it to fill completely. In this way even quite complex shapes with narrow sections and fine detail can be cast successfully.

[0016] It is known to form a thin ceramic shell using a pattern of cellular plastics, e.g. expanded polystyrene see EP-A-115402. While such shells are useful in commerce the surface formed is not sufficiently smooth to provide the excellent surface finish requested in investment casting.

[0017] A further adaptation of this process is its application to vacuum cast alloys, e.g. nickel-based or cobalt-based superalloys. In this option the alloy to be cast is melted under vacuum in a vacuum melting furnace. A bed of granular material containing the mould is positioned inside the casting chamber of the furnace; the granular material in the bed having been vibrated in advance to compact it. An inert gas, e.g. argon, is then admitted into the casting chamber and a pump is activated which draws the inert gas through the mould and the bed of granular material and then re-admits it into the casting chamber. This enhances the apparent permeability of the shell and the apparent fluidity of the alloy, producing a condition akin to the basic air-melt process but in an oxygen-free environment allowing oxidation-prone vacuum cast alloys to be processed.

[0018] The invention includes components cast by the method.

[0019] In order that the invention may be well understood it will now be described, by way of illustration only, with reference to the accompanying figures in which:

Figure 1 is a flow diagram representing the steps involved in one process of the invention, and

Figure 2 is a section through bed of granular material containing the mould immediately prior to filling the mould with molten metal.

[0020] In this case, several components were to be cast at once. Impressions of the components to be cast were produced in wax and were assembled onto a central running system to produce a wax cluster or assembly. The assembly was then immersed in a primary slurry consisting of a refractory particulate filler e.g. zircon

filler and water-based colloidal silica binder. After removing the assembly from the slurry tank, excess slurry was allowed to drain off before a stucco of granular zircon was applied to the surface by placing it in a rain sander. The assembly was then placed in a drying room with controlled temperature, humidity and air-flow, where it remained until it was dry enough to accept a second slurry and stucco coating.

[0021] The second and subsequent coatings were of back-up material, comprising a slurry of fused silica filler and water-based colloidal silica binder and a stucco of Molochite™, an alumino-silicate material produced from china clay. In all, five coatings were applied, including the primary coat. Drying times between coats ranged from 36 minutes between coats 1 and 2 to 54 minutes between coats 4 and 5. After coat 5 was applied, the mould was left for 20 hours in the drying room before removing the wax in a steam autoclave and firing at 1050°C in a gas fired kiln to remove all traces of wax. Drying conditions used throughout mould build and final dry were 23°C dry bulb temperature and 55% relative humidity.

[0022] For casting, the cold shell S was placed in a mould box 3 measuring 1m x 1m x 1m. Sub-angular silica sand 4 was then poured into the bed around the outside of the mould. The box was vibrated at a frequency of 40 - 50 Hz and displacement of 0.045 mm RMS (root mean square) for a period of 90 seconds. This compacted the sand ensuring a high bulk density and intimate contact of the sand with all areas of the mould. A vacuum of approximately 500 mm measured at the pump mercury gauge was drawn in the sand bed and steel was then poured into the cold shell via a plenum chamber 5 in the base of the box.

[0023] After casting the vacuum was turned off and the cast article was recovered from the box. The cast components conformed to the required specification without any signs of incomplete filling, mould cracking due to thermal shock or any other casting defects which could be attributable to casting into a cold mould. It was surprising that such high quality castings could be produced together from a cold shell made using a wax pattern.

[0024] The invention is not limited to the embodiments shown. For example, the top of the box may be covered by a sheet and/or protective gas may be supplied during casting.

Claims

1. A method of casting an article of molten metal, the method comprising casting the liquid metal into a supported thin ceramic shell having a smooth surface and which has not been pre-heated before ingress of the liquid metal and including the preliminary step of supporting the shell in a bed of compacted granular material and applying a vacuum to

the compact granular material while the liquid metal is being cast into the shell whereby to draw all the metal into the shell.

2. A method according to Claim 1, wherein a single charge of molten metal is used to cast a number of components forming one ceramic shell in one moulding operation.
3. A method according to Claim 2, adapted to cast a number of automotive or general commercial castings.
4. A method according to any preceding Claim, wherein the ceramic shell measures less than about 3 mm in wall thickness.
5. A method according to Claim 4, including the preliminary step of forming the ceramic shell by applying successive coatings of coating material to a wax pattern to form the defined wall thickness and removing the wax pattern to form a handleable ceramic shell.
6. A method according to Claim 5, wherein the coating material is water-based ceramic slurry and a dry granular ceramic stucco.
7. A method according to any preceding Claim, wherein the liquid metal is cast under a protective atmosphere of inert gas.
8. A method according to claim 1, the method comprising the steps of:
 - 1) forming a pattern of the component(s) to be cast and the associated runner system from wax;
 - 2) dipping the wax pattern into a tank of ceramic slurry comprising a refractory filler and a water based binder to form a coating on the pattern;
 - 3) draining the excess slurry and applying refractory granules to the coating to form a stucco layer thereon and then allowing the coating to dry;
 - 4) repeating steps (3) and (4) to form a coating about 3 mm thick;
 - 5) removing the wax and allowing the resultant shell to cool to room temperature;
 - 6) placing the shell in a mould box and surrounding it with granular filler;
 - 7) vibrating the box to compact the filler to a

high bulk density;

8) applying a vacuum to the granular filler;

9) pouring molten metal into the shell while maintaining the vacuum;

10) removing the vacuum, allowing the casting to cool and then separating it from the filter; and

11) removing the shell to provide a casting having a substantially smooth external surface.

9. A method according to Claim 8, wherein the slurry is water based.

10. A method according to Claim 8 or 9, wherein several articles are cast in the one mould box using the single charge of molten metal.

11. A method according to any of Claims 8 to 10, applied to casting articles of a superalloy, wherein the following step (7) the mould box is placed in the casting chamber of a vacuum melting furnace, an inert gas is admitted to the chamber and a pump is energised to draw inert gas through the mould box, the alloy is melted under vacuum and poured into the box whereby to form an article of superalloy and having a smooth finish.

Patentansprüche

1. Verfahren zum Gießen eines Artikels aus geschmolzenem Metall, wobei das Verfahren ein Gießen des flüssigen Metalls in einen gestützten dünnen Keramikmantel umfasst, der eine glatte Oberfläche aufweist und vor dem Eindringen des flüssigen Metalls nicht vorgeheizt worden ist, und den vorhergehenden Schritt des Stützens des Mantels in einem Bett aus verdichtetem granularem Material und Anlegen eines Vakuums an das dichte granulare Material umfasst, während das flüssige Metall in den Mantel gegossen wird, wodurch das gesamte Metall in den Mantel gezogen wird.
2. Verfahren nach Anspruch 1, wobei eine einzige Charge geschmolzenen Metalls verwendet wird, um eine Zahl von Komponenten zu gießen, wobei ein Keramikmantel in einer Gießoperation gebildet wird.
3. Verfahren nach Anspruch 2, das dazu ausgelegt ist, eine Zahl von Kraftfahrzeug- oder allgemeinen industriellen Gußerzeugnissen zu gießen.
4. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Wanddicke des Keramikmantels we-

niger als ungefähr 3 mm beträgt.

5. Verfahren nach Anspruch 4, umfassend den vorhergehenden Schritt des Formens des Keramikmantels durch aufeinanderfolgendes Aufbringen von Schichten eines Beschichtungsmaterials auf ein Wachsmuster, um die definierte Wanddicke zu bilden, und durch Entfernen des Wachsmusters, um einen handhabbaren Keramikmantel zu bilden.

6. Verfahren nach Anspruch 5, wobei das Beschichtungsmaterial keramischer Schlamm auf Wasserbasis und ein trockener granularer Keramikstück ist.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei das flüssige Metall unter einer Inertgas-Schutzatmosphäre gegossen wird.

8. Verfahren nach Anspruch 1, wobei das Verfahren die Schritte umfasst:

- 1) Bilden eines Musters der zu gießenden Komponente(n) und des zugeordneten Angußsystems aus Wachs;
- 2) Eintauchen des Wachsmusters in einen Tank mit keramischem Schlamm, umfassend einen feuerfesten Füller sowie ein Bindemittel auf Wasserbasis, um eine Beschichtung auf dem Muster zu bilden;
- 3) Ablaufenlassen des überschüssigen Schlamms und Aufbringen von feuerfesten Körnern auf die Beschichtung, um eine Stuckschicht darauf zu bilden, und anschließendes Trocknenlassen der Beschichtung;
- 4) Wiederholen der Schritte (3) und (4), um eine Beschichtung mit einer Dicke von ungefähr 3 mm zu bilden;
- 5) Entfernen des Wachses und Abkühlenlassen des resultierenden Mantels auf Raumtemperatur;
- 6) Anordnen des Mantels in einen Formkasten und Umgeben desselben mit granularem Füller;
- 7) Schütteln des Kastens, um den Füller auf eine hohe Füllhöhe zu verdichten;
- 8) Anlegen eines Vakuums an den granularen Füller;
- 9) Gießen geschmolzenen Metalls in den Mantel, während das Vakuum beibehalten wird;
- 10) Entfernen des Vakuums, Abkühlenlassen des Gußerzeugnisses und anschließendes Trennen desselben vom Füller; und
- 11) Entfernen des Mantels, um ein Gußerzeugnis zu liefern, das eine im Wesentlichen glatte Außenoberfläche aufweist.

9. Verfahren nach Anspruch 8, bei dem der Schlamm

ein Schlamm auf Wasserbasis ist.

10. Verfahren nach Anspruch 8 oder 9, wobei verschiedene Artikel in dem einen Formkasten unter Verwendung der einzigen Charge geschmolzenen Metalls gegossen werden.

11. Verfahren nach einem der Ansprüche 8 bis 10, angewandt auf das Gießen von Artikeln aus einer Superlegierung, wobei im folgenden Schritt (7) der Formkasten in die Gießkammer eines Vakuumschmelzofens gesetzt wird, ein Inertgas in die Kammer eingelassen und eine Pumpe eingeschaltet wird, um Inertgas durch den Formkasten zu saugen, und die Legierung unter Vakuum geschmolzen und in den Kasten gegossen wird, um hierdurch einen Artikel aus der Superlegierung und mit einer glatten Ausführung zu bilden.

Revendications

1. Procédé de coulage d'un article de métal en fusion, le procédé comprenant la coulée dm métal liquide dans une coquille mince en céramique supportée et ayant une surface lisse et qui n'a pas été préchauffée avant l'introduction du métal liquide et comprenant l'étape préliminaire consistant à supporter la coquille dans un lit de matériau granulaire compacté et à appliquer un vide au matériau granulaire compact pendant que la métal liquide est coulé dans la coquille, permettant ainsi d'amener la totalité du métal dans la coquille.
2. Procédé selon la revendication 1, dans lequel on utilise une seule charge de métal en fusion pour couler un certain nombre de composants formant une seule coquille de céramique en une seule opération de moulage.
3. Procédé selon la revendication 2, permettant de couler un certain nombre de pièces coulées automobiles ou industrielles générales.
4. Procédé selon l'une quelconque des revendications précédentes, dans lequel la coquille de céramique présente une épaisseur de paroi inférieure à environ 3 mm.
5. Procédé selon la revendication 4, comprenant l'étape préliminaire consistant à former la coquille de céramique en appliquant des couches successives d'un matériau de revêtement sur un modèle en cire pour former l'épaisseur de paroi définie et enlever le modèle en cire pour former une coquille de céramique manipulable.
6. Procédé selon la revendication 5, dans lequel le

matériau de revêtement est un coulis de céramique à base d'eau et un stuc de céramique granulaire sec.

7. Procédé selon l'une quelconque des revendications précédentes, dans lequel le métal liquide est coulé sous une atmosphère protectrice de gaz inerte.

8. Procédé selon la revendication 1, le procédé comprenant les étapes consistant à :

1) former un modèle du (des) composants (s) à couler et le système de canal de coulée associé en cire;

2) plonger le modèle de cire dans un réservoir de coulis de céramique comprenant un produit de remplissage réfractaire et un liant à base d'eau pour former un revêtement sur le modèle;

3) évacuer l'excédent de coulis et appliquer des granulés réfractaires sur le revêtement pour y former une couche de stuc et laisser ensuite sécher le revêtement;

4) répéter les étapes (3) et (4) pour former un revêtement d'environ 3 mm d'épaisseur;

5) enlever la cire et laisser refroidir la coquille résultante à température ambiante;

6) placer la coquille dans un châssis de moule et l'entourer de produit de remplissage granulaire;

7) faire vibrer le châssis pour compacter la matière de charge à une densité apparente élevée;

8) appliquer un vide au produit de remplissage granulaire;

9) couler le métal en fusion dans la coquille tout en maintenant le vide;

10) enlever le vide, laisser refroidir la pièce coulée et ensuite la séparer du produit de remplissage; et

11) enlever la coquille pour obtenir une pièce coulée ayant une surface extérieure sensiblement lisse.

9. Procédé selon la revendication 8, dans lequel le coulis est à base d'eau.

10. Procédé selon la revendication 8 ou 9, dans lequel plusieurs articles sont coulés dans le châssis de

moule en utilisant l'unique charge de métal en fusion.

11. Procédé selon l'une quelconque des revendications 8 à 10, appliqué à des articles coulés d'un superalliage, dans lequel dans l'étape suivante (7) le châssis de moule est placé dans la chambre de coulée d'un four de fusion sous vide, un gaz inerte est admis dans la chambre et une pompe est mise en circuit pour aspirer le gaz inerte à travers le châssis de moule, l'alliage est mis en fusion sous vide et versé dans le châssis de façon à former un article de superalliage et présentant une finition lisse.

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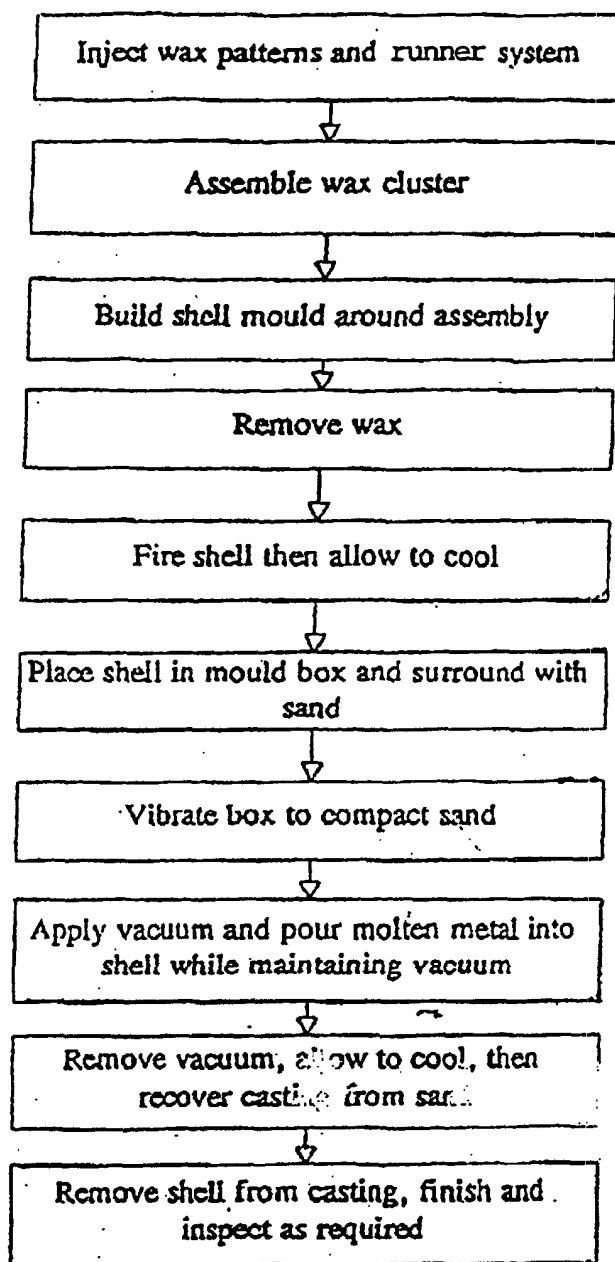


Figure 1

