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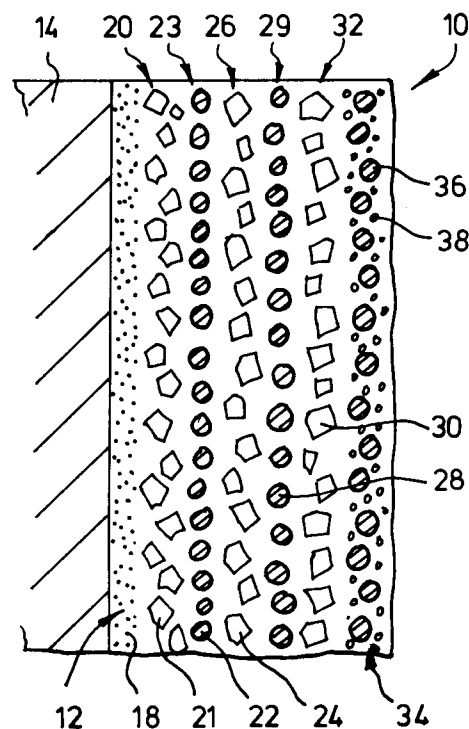
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(57) A casting mould and method for the manufacture thereof are described. The mould comprises a ceramic layered structure including particles, and containing voids formed by the removal of fugitive particulate material (22,28,36). The purpose of the voids is to improve the insulative properties of the mould.

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The present invention relates particularly, though not exclusively to moulds for producing precision cast articles.

In, for example, the precision casting of components for turbine machinery it is virtually universal practice to employ the technique known as investment or lost-wax casting.

Investment casting generally requires that a pattern or facsimile of the component to be cast is first made in a wax material. The wax pattern is then coated by dipping with a face, or prime ceramic slurry of a controlled composition and rheology, the dipped pattern then receives a stucco coating of dry grains of a ceramic material. The ceramic material commonly comprises one or more selected from the group which includes alumina, silica, alumino-silicates, zirconium silicate, for example, and is of a controlled particle size range. The dipped and stucco coated pattern is then dried and given a second slurry coating, again of a carefully controlled composition and rheology, which again also receives a second stucco coating of ceramic material. The desired mould is built-up in this fashion with several slurry and stucco repeat coatings until the desired mould thickness is achieved. The wax pattern is finally removed, usually in a steam autoclave, to leave a mould cavity having the desired shape. The resulting "green" or unfired mould is then fired under a precisely controlled heating cycle to increase its strength and to burn off residual wax. The binder material in the slurry is often colloidal silica, in which case, the strength increase is achieved by creation of siloxane bonds within the ceramic matrix. Such moulds possess a degree of inherent porosity, typically up to 30 vol.%, and are characterised by thermal diffusivity values in the range 0.7 to 1.6 mm²s⁻¹.

There are two principal casting techniques whereby turbine blades, for example, are cast. These two techniques result in three different metal grain structures in the resulting casting, depending on the process controls applied to the solidification of the cast metal.

The first and oldest technique, and also the technique which is employed to produce the majority of precision cast components used in gas turbine engines, for example, is that which results in a component having an equiaxed grain structure. In this technique, molten metal is poured into a preheated mould which is then allowed to cool by radiation of heat from the mould exterior. The metal solidifies by nucleation and growth at many sites throughout the casting to give an equiaxed grain structure.

The second technique is directional solidification where, depending upon the process constraints applied, the component may solidify either in polycrystalline form with a structure made up of

directionally aligned columnar crystals or it may solidify in the form of a single crystal.

It is with the first technique for forming components with equiaxed grain structures that the present invention is primarily concerned.

Turbine components, especially blades, frequently employ an airfoil portion. This particular portion is often significantly thinner in section than the remainder of the component. These thin airfoil sections, and indeed any other thin casting sections, are prone to premature solidification due to the lower ratio of hot metal to cooler mould. If solidification is too rapid, defects such as cold-shuts, misruns and shrinkage porosity frequently occur.

European patent application No. 0,399,727 addresses the same problem and seeks to provide a mould having improved insulative properties by coating a disposable pattern with ceramic slurry and applying one or more layers of hollow granular bubble material. However, the bubble walls are dense and relatively conductive, allowing heat to be transferred quickly around the bubble void.

It is an object of the present invention to provide a mould and a method of making a mould which has significantly improved insulative properties over known moulds.

According to a first aspect of the present invention, there is provided a method of making a mould for the casting of metal articles, the method comprising the steps of coating a pattern of the article to be cast with a ceramic slurry, dusting the coated pattern with ceramic particles to form a face layer, drying the slurry coated and dusted layer so formed, coating the coated and dried pattern with a slurry for a second time and dusting with a particulate material and again drying, repeating the slurry coating, dusting with particulate material and drying cycles until a desired thickness of mould material has been built-up wherein at least one of the dusting steps employs fugitive particulate material which is removed during a subsequent heating step to leave residual voids in a ceramic matrix.

In one embodiment of a method according to the present invention the fugitive particulate material may be a polymeric plastics material such as, for example, expanded polystyrene.

The heating step to remove the fugitive material may be a firing process to which the mould is subjected.

The thermal diffusivity of the resulting mould may be controlled through adjustment of the sizes of particles of fugitive material included in, and the number of, layers from which are formed layers having voids therein.

In some cases, it may be desirable that a stucco coating step for a layer of particulate material may be effected with a mixture of both fu-

gitive material particles and ceramic particles. In this manner, more accurate control of the thermal diffusivity may be effected.

Preferably, the ceramic matrix may comprise low density, and hence low thermal conductivity, refractories such as, for example, silica or high silica content alumino-silicates.

According to a second aspect of the present invention, there is provided a mould for the casting of metal articles, the method of making the mould includes the steps of coating a pattern of the article to be cast with a ceramic slurry, dusting the coated pattern with ceramic particles to form a face layer, drying the slurry coated and dusted layer so formed, coating the coated and dried pattern with a slurry for a second time and dusting with a particulate material and again drying, repeating the slurry coating, dusting with particulate material and drying cycle until a desired thickness of mould material has been built up, thereby the mould comprising a face layer adjacent a metal to be cast and a plurality of successive layers wherein at least one of the successive layers comprises a ceramic matrix having voids therein formed by the removal of a fugitive particulate material.

Moulds made in accordance with the method of the present invention have resulted in thermal diffusivity value of 0.5 to 0.7 mm²s⁻¹.

Where there is more than one layer containing voids, these may be interspersed with layers having only ceramic stucco particles contained therein to maintain sufficient mould strength to withstand metallostatic pressures on casting.

In order that the present invention may be more fully understood an example will now be described by way of illustration only with reference to the accompanying drawing, which shows a schematic representation of a section taken through part of the thickness of a mould in accordance with the present invention.

Referring now to the drawing and where the mould wall is designated at 10. The mould wall comprises a face layer 12 which is initially adjacent a wax pattern 14 and, after pattern removal and firing of the mould, is adjacent the cast metal. Initially the face layer comprises a slurry of a colloidal, or otherwise finely divided, ceramic material.

Any such slurry may include further finely divided material, and/or at least one material in the form of particles of a size conventionally referred to as a grit size. In the illustrated example the slurry forming the face layer 12 is of colloidal silica having a filler of zircon flour therein. The wax pattern 14 is coated by being dipped into the slurry, and is then dusted with fine zircon sand particles indicated at 18. The dipped and dusted pattern is then dried and subsequently redipped in a similar slurry

to the first, but having a controlled lower viscosity. The dipped pattern is then dusted with -22 to +50 B.S mesh Molochite (trade mark) stucco grains 21, and dried again to form the layer 20. This is followed by a further slurry dipping step, after which the dipped pattern is given a stucco coating of expanded polystyrene beads 22 having a size, in this instance, in the range from 1 to 1.5 mm in diameter. After drying to form the layer 23, the pattern is recoated with a slurry having a composition of about 30 wt% colloidal silica (25% concentration), 50 wt% Molochite flour of about 200 B.S mesh size and 20 wt% Molochite grains of -22 to +50 B.S mesh size. This coating is dusted with Molochite grains and dried. The Molochite grains are indicated at 24, and are in a layer indicated at 26. The cycle of dipping with slurry, stucco coating and drying is repeated until a sufficient mould wall thickness has been established. In the example shown a second stucco coating of polystyrene beads is shown at 28, in relation to a layer 29; followed by a second stucco coating of Molochite grains 30 in relation to a layer 32. Layer 34 is formed from a dipped coating of a ceramic slurry dusted with a mixture of both fugitive material particles 36 and ceramic particles 38. Thus a matrix is built up in successive layers, and so that the ceramic material has particles embedded therein. After the required mould wall thickness has been built up the mould is finally dried and the wax pattern 14 removed, usually in a steam autoclave. The mould is then subjected to a firing cycle to burn-off the polystyrene beads 22, 28, leaving behind voids of the same size in their place, and to strengthen the matrix by creation of siloxane bonds. A typical burn-off and firing cycle may comprise heating the mould to 800 to 1000°C for 30 to 45 minutes. Because of the inherent porosity levels of up to 30 vol% in the ceramic matrix of these types of investment casting mould, it is possible to burn-off the polystyrene, or any other polymeric material, without the danger of rupturing the mould.

Moulds were prepared according to the example given above and the schematic representation shown in the drawing. The moulds each contained four nozzle guide vane segment cavities, each segment comprising six airfoils. The airfoils were 160 mm in length, 30 mm chordal dimension, and approximately 0.6 mm maximum thickness. The moulds were cast using preheat and pouring temperatures typical for casting nickel-based superalloys. The resulting cast components were compared with castings made using a conventional zircon and alumino-silicate mould.

There was no evidence of premature solidification in the form of misrun, and the components were of sufficient soundness to make them accept-

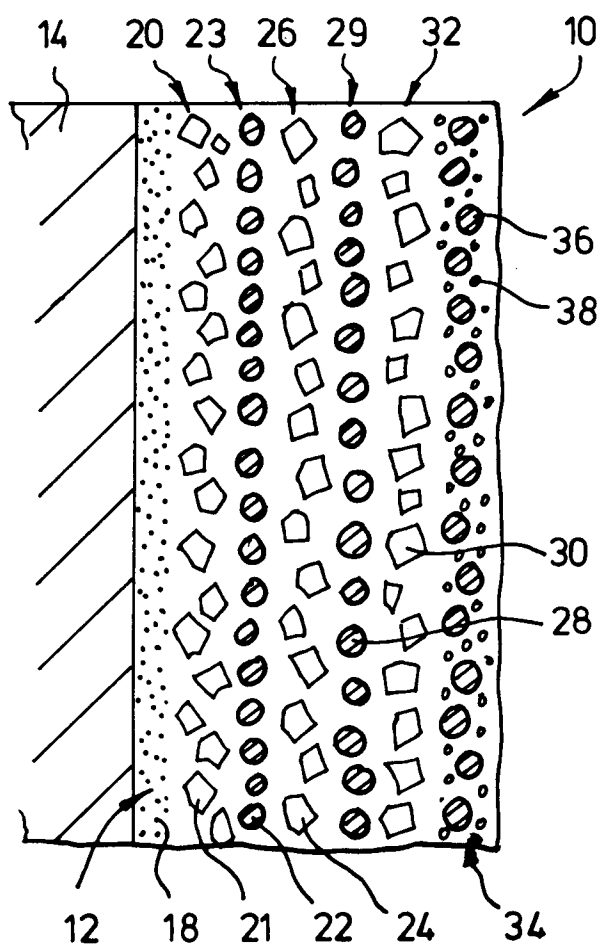
able to specification without the need for post-cast hot isostatic pressing. Acceptable casting soundness could not be achieved using conventional moulds without resorting to post-cast hot isostatic pressing.

Claims

1. A method of making a mould for the casting of metal articles, the method comprising the steps of coating a pattern of the article to be cast with a ceramic slurry, dusting the coated pattern with ceramic particles to form a face layer, drying the slurry coated and dusted layer so formed, coating the coated and dried pattern with a slurry for a second time and dusting with a particulate material and again drying, repeating the slurry coating, dusting with particulate material and drying cycles until a desired thickness of mould material has been built-up, characterised in that at least one of the dusting steps employs fugitive particulate material which is removed during a subsequent heating step to leave residual voids in a ceramic matrix. 10
2. A method according to claim 1 characterised in that the fugitive particulate material is a polymeric plastics material. 15
3. A method according to claim 2 characterised in that the polymeric material is expanded polystyrene. 20
4. A method according to any one preceding claim characterised in that the at least one dusting step employs both ceramic and fugitive particulate material. 25
5. A method according to any one preceding claim characterised in that the ceramic matrix comprises low density refractories. 30
6. A method according to claim 5 characterised in that the low density refractories are selected from the group comprising silica and aluminosilicates. 35
7. A method according to any one preceding claim characterised in that the heating step is a mould firing process. 40
8. A mould for the casting of metal articles, the method of making the mould includes the steps of coating a pattern of the article to be cast with a ceramic slurry, dusting the coated pattern with ceramic particles to form a face layer, drying the slurry coated and dusted layer 45

er so formed, coating the coated and dried pattern with a slurry for a second time and dusting with a particulate material and again drying, repeating the slurry coating, dusting with particulate material and drying cycle until a desired thickness of mould material has been built up, thereby the mould comprising a face layer adjacent a metal to be cast and a plurality of successive layers, characterised in that at least one of the successive layers comprises a ceramic matrix having voids therein formed by the removal of a fugitive particulate material.

9. A mould according to claim 8 characterised in that the thermal diffusivity value lies in the range from 0.5 to 0.7mm²s⁻¹. 50
10. A mould according to either claim 8 or claim 9 characterised in that the voids are from about 1 to 1.5 mm in diameter. 55
11. A mould according to claim 8, or claim 9, or claim 10, characterised in that there is more than one void containing layer, and these are interspersed with layers having only ceramic stucco particles contained therein.
12. A mould according to any one preceding claim from 8 to 11 characterised in that a void containing layer also contains ceramic stucco particles.





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EUROPEAN SEARCH REPORT

Application Number

EP 92 20 0599

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,X	FR-A-2 654 655 (MOREAU) 24 May 1991 * page 1, line 1 - page 2, line 3 * ---	1-12	B22C1/16 B22C9/04
X	US-A-3 367 393 (DENVILLE ET AL.) 6 February 1968 * column 1, line 27 - column 2, line 14 * * claims * * figures * ---	1-12	
X	GB-A-1 410 634 (IMPERIAL CHEMICAL INDUSTRIES LIMITED) 22 October 1975 * page 2, line 33 - line 58 * ---	1-12	
X	FR-A-1 515 784 (ALLISON ET AL.) 1 March 1968 * résumé * * figures * ---	1-12	
X	DE-A-3 334 457 (FICHTEL & SACHS AG) 11 April 1985 * claims * * page 6, line 1 - page 7, line 21 * * figure * ---	1-12	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	JAPS, Japanese Abstracts Database, Japanese Patent Office, Tokyo, JP AD=08-01-88 & JP-A-62168632 (MITSUI ENG ET AL.) 24-July-1984 * abstract * -----	2,3	B22C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05 JUNE 1992	Examiner M. Riba Vilanova
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			