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54 **Investment casting mould.**

57 A method and material for the manufacture of investment casting moulds are described. The moulds so produced comprise relatively large alumina particles contained in a matrix of fine alumina flour and a siliceous bonding phase. Preferably at least a part of the alumina flour is constituted by alumina known as "reactive alumina". Preferably the shell mould is fired at a temperature sufficiently high to allow at least a part of the silica to combine with the alumina flour to form mullite in the matrix.

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Investment Casting Mould

The present invention relates to a mould and to a method for the manufacture of moulds for investment casting.

In the manufacture of components such as, for example, blades and nozzle guide vanes for gas turbine engines the well known technique of precision investment casting is frequently employed. This technique employs a ceramic shell mould formed around, for example, a wax pattern of the component to be cast. Heretofore, the bulk of such ceramic shell moulds have normally comprised coarse alumina or aluminosilicate particles within a zircon flour matrix bonded with silica.

Generally speaking, known ceramic moulds are adequate for the casting of components with microstructures of equiaxed grains. Where the components are required to be of directionally solidified, columnar grain structure (DS) or of single crystal structure (SX), however, known mould materials have certain disadvantages.

The casting procedure for the production of DS and SX components requires that the mould be maintained for several hours above the liquidus temperature of the alloy being cast. Such temperatures may exceed 1500°C. At these temperatures the strength and stiffness of the mould may be inadequate to withstand the prolonged metallostatic pressure of the molten alloy without either rupture or unacceptable distortion. This limitation is primarily associated with viscous creep of the siliceous binder phase.

Existing DS and SX shell moulds generally use a zircon flour filler material i.e. crushed zircon sand; a natural mineral which is becoming scarce and consequently increasingly expensive.

An object of the present invention is to provide a mould having improved high temperature strength and creep resistance than known moulds.

According to a first aspect of the present invention a method for the manufacture of a ceramic shell mould comprises the steps of making a slurry comprising colloidal silica having alumina flour therein, coating a pattern of a component to be cast with the slurry, dusting the coated pattern with alumina particles, drying the coated and dusted pattern, dipping the pattern into a slurry for a second time, redusting with alumina particles and drying again, repeating the slurry dipping, dusting and drying stages at least one further time, removing the pattern and then firing the shell mould.

For the purpose of this specification a "flour" is defined as a ceramic powder wherein substantially all particles are less than 100 micro metres in diameter.

In a preferred embodiment of the method of the present invention the dried shell mould so formed is fired at a temperature sufficiently high to allow at least a part of the silica to combine with the alumina flour to form mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) in the matrix binder phase.

The shell may be fired either in a specific firing operation after drying and removal of the pattern or during preheating and "soaking" of the mould prior to the casting operation. Temperatures in excess of 1400°C are preferred.

Preferably at least part of the alumina in the slurry should be in the form generally known as "reactive alumina". Such alumina has a high specific surface area and a very small particle size. Examples of suitable commercially available alumina powders are those of the "RA" series (trademark) produced by British Alcan Aluminium Limited and those by Alcoa under the code CT9 (trade mark). Preferably the slurry may contain from 1 to 25 wt% of reactive alumina and up to 70 wt% of other alumina flour. More preferably the matrix slurry may contain from 10 to 20 wt% of reactive alumina.

The matrix slurry may optionally contain up to 5 wt% of fine titania powder which may act as a catalyst in the formation of mullite in the matrix. It has been found that additions greater than 5 wt% confer no additional practical benefit.

According to a second aspect of the present invention there is provided a ceramic shell mould when made by the method of the first aspect.

It has been found that the new mould material possesses greater thermal diffusivity than conventional materials. This is advantageous, especially in the case of DS and SX castings in that it allows more precise control of heat extraction thereby reducing the risk of nucleating stray grains in the so-called "mushy" region ahead of the solidification front.

A further advantage conferred by the greatly improved high temperature strength properties of the new material is that thinner shell moulds may be used. This in turn also enhances control of heat extraction during solidification.

Shell moulds of the present invention contain only synthetic "starting" materials which are both readily available and of relatively high purity compared to naturally occurring minerals such as zircon.

In order that the present invention may be more fully understood examples will now be described by

way of illustration only.

The accompanying figure shows a graph of creep displacement against time for conventional mould materials and for materials according to the present invention.

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Examples

Moulds for testing were prepared by the following method.

A wax pattern was dipped in a slurry of the first composition shown in Table 1.

10 The dipped pattern was then dusted with 80's mesh (B.S.) fused alumina and dried.

The coated pattern was then dipped in a more dilute version of the same slurry and then dusted with 28/48's mesh (B.S.) Tabular Alumina and then dried.

The sample was then dipped in a slurry of the second composition given in Table 1, dusted with 28/48's mesh (B.S.) Tabular Alumina and dried.

15 This last dipping, dusting and drying sequence was repeated as required.

The final stage in building the shell mould was a slurry dip only followed by drying.

Each sample had seven slurry and six dusting coats.

The wax pattern was removed by a known method.

Some of the moulds were fired at 960°C for 30 minutes. These were designated material "A2".

20 Others were fired at 1500°C for 2 hours. These were designated material "A2'".

Table 1

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Slurry	Colloidal silica suspension	325 alumina	28/48 alumina	Reactive alumina	Titania
1st Comp	25.4	58.6	-	14.6	1.4
2nd "	20.3	50.7	15.1	12.7	1.2

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All the above figures are in weight %. The colloidal silica contained approximately 30 wt% of silica.

Further moulds were made using conventional colloidal silica/zircon flour slurry by conventional current methods and given the same number of slurry and dusting coats as A2 and A2'. These moulds were fired at 960°C for 30 minutes. This material was designated "Y.D.S."

35 Modulus of rupture tests were carried out at 1050°C on the prepared samples. The results are given in Table 2 below.

Table 2

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Material	MOR 1050 ° C/MPa	Av.Shell Thickness (mm)	Av.Fail Load 1050 ° C/N
Y.D.S.	15.0	4.6	67.5
A2	24.2	4.7	108.9
A2'	30.0	4.7	135.0

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As may be seen from Table 2 the strength of the A2 material under equivalent processing conditions is about 60% greater than the Y.D.S material and the A2' material is 100% stronger than the Y.D.S. material.

50 The important improvement of the A2' material over the Y.D.S material is in creep resistance as shown by the creep tests in the accompanying figure. Conditions for the tests were; test temperature 1420°C; test bars fired at 1500° for approximately 2 hours and soaked at the test temperatures for approximately 6 minutes prior to testing; test bar section was 4.6 x 25.0 mm and a 750g static load was used. The conventional Y.D.S. material failed in under 20 seconds with a displacement of 0.6 mm whereas the A2' material showed steady creep with a displacement of 0.33 mm after 7 minutes. In casting DS and SX components creep resistance of the shell mould is of greater importance.

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The thermal diffusivity of the A2 and A2' materials was 4.24 mm² sec⁻¹ compared with 1.74 mm² sec⁻¹ for the Y.D.S. material.

Mullite was detected by X-ray diffraction analysis in A2' but not in A2 material.

Examination of the A2 material by optical microscopy showed extensive bonding of the large alumina grains with the matrix which consisted of the small alumina particles bonded with mullite. In the Y.D.S material, in contrast, there was very little bonding of the large alumina particles to the matrix of small zircon particles bonded with silicate glass.

Claims

1. A method for the manufacture of a ceramic shell mould, the method comprising the steps of making a slurry comprising colloidal silica having ceramic flour therein, coating a pattern of a component to be cast with the slurry, dusting the coated pattern with alumina particles, drying the coated and dusted pattern, dipping the dried pattern into a slurry for a second time, redusting with alumina particles and drying again, repeating the slurry dipping, dusting and drying stages at least one further time, removing the pattern and then firing the shell mould characterised in that the ceramic flour comprises alumina.
2. A method according to Claim 1 characterised in that the mould is fired at a temperature sufficiently high to form mullite in the matrix.
3. A method according to either Claim 1 or Claim 2 characterised in that the firing temperature is above 1400°C.
4. A method according to any one preceding claim characterised in that the firing of the mould is carried out as a specific operation.
5. A method according to any one of Claims 1 to 3 characterised in that the firing of the mould is performed during preheating immediately prior to metal casting
6. A method according to any one preceding claim characterised in that at least a part of the alumina in the slurry is in the form of reactive alumina.
7. A method according to Claim 6 characterised in that the slurry contains from 1 to 25 wt% of reactive alumina.
8. A method according to Claim 7 characterised in that the slurry contains from 10 to 20 wt% of reactive alumina.
9. A method according to any one preceding claim characterised in that the slurry contains up to 5 wt% of titania.
10. A ceramic shell mould characterised by being made by any one of the method claims from Claim 1 to Claim 9.

