MOLD COMPOSITION AND PROCESS
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7 Claims. (Cl. 106—38.9)

The present invention relates to mold materials which are particularly suited for precision casting and to processes of making molds.

A purpose of the invention is to produce a harder and stronger mold for precision casting.

A further purpose is to obtain a mold material which is not reactive with the oxide slags formed in casting high melting point alloys containing aluminum and/or titanium, and which is of Inconel-X type having the composition set forth below.

A further purpose is to reduce the difficulty of forming a molding material for precision casting.

A further purpose is to increase the refractoriness of molding materials having fine surface quality and high tolerance.

A further purpose is to obtain a molding material which is sufficiently strong and resistant to abrasion to permit removal of a pattern by a sliding motion.

A further purpose is to obtain a precision casting material which can be used in thin sections because of its great strength.

Further purposes appear in the specification and in the claims.

In the precision casting practice, an investment or other similar molding material is formed into a mold around a pattern, which may be of a destructible material such as wax or plastic, or may be of metal. The material of the mold has formed a limitation in the process.

In the most common prior art procedure, to obtain metal castings having a good finish and close tolerance, the wax pattern is placed in a flask and a slurry forming the investment is allowed to set around the pattern until it becomes hard and the pattern is melted or burned out leaving the finished mold. This process is subject to the great economic disadvantages that a new pattern must be used for each casting. In accordance with the procedure developed by the present inventor, a permanent pattern may be used.

In the lost wax process there are at least five steps from the production of the master pattern to the forming of the casting, at which steps contours must be transferred from one object to another. A certain amount of loss in precision is inevitable in one of these steps, and, therefore, especially when great care is not used, inaccuracy and loss of tolerance are likely to occur. In this connection it should be noted also that the removal of the destructible pattern in the lost wax process involves heating before the destructible pattern melts, which often causes disruptive expansion, followed by burning off and preheating of the investment, which necessarily changes the investment dimensions. In the process of the present invention there are at most three steps between the production of the master pattern and the making of the casting, with elimination of the disruptive effect of removal of the destructible pattern so that very much higher tolerances are possible, and high tolerances are possible with less care and skill than in the lost wax process.

In certain prior art processes it is necessary or desirable to apply a mold wax to the investment prior to casting, and use of the mold wax results in appreciable change in dimensions both due to erosion and uneven build-up. One of the advantages of the present invention is that no mold wax is required and in fact the use of a mold wax is undesirable.

Prior art molds formed by the methods used in the ceramic industry have involved the use of clay bodies with high forming pressure and high firing temperatures. Molds have also been made by ramming sodium silicate-silica flour mixtures. Plaster of Paris molds have also been used. These have been the best of the earlier methods for obtaining foraminous molds from a permanent pattern. Each of these methods has certain serious disadvantages which the procedure according to the present invention lacks. The ceramic process requires high pressures and high temperature kilns which are not required in following the procedure of the present invention. Furthermore the high firing temperatures tend to distort the molds. The plaster of Paris molds are limited to use with nonferrous metals while the molds of the present invention may be used with iron and steel and other ferrous alloys.

The sodium silicate-silica flour molds have several disadvantages, especially the poor resistance to heat shock, the necessity for preheating the molds to approximately 500° C. before pouring metal into them, the need for furnace cooling the molds to approximately 200° C. and the low green strength.

I have previously developed a mold composition embodied in my application Serial No. 94,055, filed May 18, 1949, for Mold Composition for Precision Casting and Method of Forming Mold, since issued as U. S. Patent 2,586,814, granted February 26, 1952. This mold composition offers many advantages that are above referred to. It employs a silica-base material. There are, however, certain disadvantages in the silica-base material of my prior application which the present development overcomes, as noted below.

The mold composition of the present invention bakes to a harder and stronger mold than does the silica-base material of my prior patent application.

The mold material of my prior invention also is not suitable for use in casting high melting point alloys in which aluminum and/or titanium is an alloying ingredient, such as "Inconel-X," an alloy of the following nominal composition:

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.04</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.50</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.40</td>
</tr>
<tr>
<td>Chromium</td>
<td>15.00</td>
</tr>
<tr>
<td>Nickel</td>
<td>73.00</td>
</tr>
<tr>
<td>Columbium</td>
<td>1.00</td>
</tr>
<tr>
<td>Titanium</td>
<td>7.0</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.7</td>
</tr>
</tbody>
</table>

since the oxide slags present react with the silica-base material. The composition of the present invention is excellent for casting high melting point alloys in which aluminum and/or titanium is an alloying ingredient, such as "Inconel-X." This makes it very useful for turbine blades and other similar castings.

The silica-base mold composition of my prior invention is not as easy to form into molds as is the composition of the present invention. Thus the composition of the present invention cuts down molding time.

The composition of the present invention also is more refractory than the silica-base mold material of my prior invention. This enables me to preheat the mold to a higher temperature before the casting is poured without breaking down or fusing the mold material. This is important in casting alloys of very high melting point such as 2500° F. to 3500° F. Also due to the greater refractoriness and less reactive character of the mold composition of the present invention much less care is required in the choice of mold temperature to obtain good castings.

The mold material of the present invention, in common with the material of my prior invention, has a very fine textured surface, which gives good surface on the
castings. The tolerance is excellent, being at least as good as ± or −0.005 inch.

The mold material of the present invention by virtue of its strength and resistance to abrasion can be used with castings of ferrous or non-ferrous permanent materials which are removed by sliding motion, as for example by pulling out without drag or by unscrewing a threaded portion.

The mold material of the invention by virtue of its high strength is applicable in thin wall sections in which sufficient permeability can be obtained.

The mold material of the invention is applicable in the castings of iron and steel containing less than 0.75 percent of the alloy, and can be employed in making castings which are utilized without machining or with a minimum of machining.

The mold material of the present invention comprises essentially a mixture of from 85 to 98 percent by weight of aluminous material of the character of fused alumina, containing 2 percent clay and the 25 parts of water containing at least 70 percent of aluminum oxide, with from 15 percent to 2 percent by weight of a swelling clay such as bentonite and with from 10 to 25 parts by weight of water added to 100 parts of the clay ingredients. The aluminous mineral will be predominantly in the form of particles through 200 mesh per linear inch, and preferably 85 percent of the aluminous mineral content of the mold will be in the form of particles through 200 mesh, and the balance will also preferably be in the form of particles through 100 mesh per linear inch.

The aluminous material may be an alumina mineral such as fused alumina, or may be an aluminous mineral having silica as an impurity such as fused silicous alumina, or may be an aluminum silicate such as an aluminous mullite, provided in any case that the content of aluminum oxide is in excess of 70 percent by weight.

The aluminous mineral of the character of fused alumina, fused silicous alumina or aluminous mullite is suitably incorporated with the swelling clay such as bentonite, and the predetermined amount of water is added to make the mold composition of the invention. The mold composition when rammed into a mold pattern, after which the pattern is removed, and the mold is baked at a temperature of 450°F. or above, during which the mold undergoes an irreversible reaction.

The mold composition of the invention, while it may contain 85 to 98 percent of the aluminous mineral of the character of fused alumina, fused silicous alumina or aluminous mullite, the aluminous powders may be either in the form of particles through 200 mesh containing 95 to 98 percent of the aluminous mineral. With the range of 85 to 98 percent by weight of the aluminous mineral of the character of fused alumina, fused silicous alumina or aluminous mullite, the swellable clay will range between 5 percent and 2 percent by weight. The water content for the wider range will be between 10 and 25 parts of water by weight per 100 parts of the dry ingredients in the water content for the narrower range will be between 10 and 22 parts by weight per 100 parts of the dry ingredients.

The 10 parts of water is preferably used with mixtures containing 2 percent clay and the 25 parts of water is preferably used with mixtures containing 15 percent clay, intermediate clay contents requiring intermediate water additions. The water content of this molding material is determined by the clay content, since a reduction of clay content down to 2 percent will not seriously affect the green or the baked strength of the mold, but a reduction of the water content below the optimum for the clay content used will so reduce the green and the baked strength of the mold as to render it unsuitable in some cases. It is most notable that the water content of the original mold composition has a very pronounced effect on the strength of the mold after all the water has been driven off by heat. Too much water likewise decreases green strength very materially very sticky and hard to work, and causing the molds to crack during baking.

In the best embodiment of the invention, 1 will employ 95 percent by weight of aluminous mineral of the character as fused silicous alumina, containing 2 percent clay, 85 percent by weight of which passes through 200 mesh per linear inch and 5 percent of swelling clay such as bentonite, with 22 parts of water added to 100 parts by weight of dry ingredients.

The molding material within the composition ranges given above is thoroughly mixed dry, the appropriate amount of water is added, and the mixture is then screened through a 4 mesh per linear inch screen to completely mix the components. The mixture is then ready for use and is fairly dry and quite light and fluffy. The molding compound is now rammed into a flask around a pattern to produce a green mold having excellent strength, surface and accuracy.

The ramming of the mold can be done by hand, by impact, or under molding pressure, it being noted that excellent results are obtained by molding under a pressure of approximately 2 pounds per square inch.

After ramming, the green mold has such strength that the pattern can be removed by a steady pull or by jarring if it clears, without damaging the mold and without endangering the accuracy of the casting. Furthermore the green mold is of such exceptional strength that it is feasible to withdraw a pattern having a bend or twist so that it must follow a curved or cored screw path in the departure from the mold. Furthermore such a pattern can be withdrawn along such a curved path by violent jarring action without deforming the mold. Patterns with twist or bend in the pattern with no draft such as gas turbine compressor blades and airfoil blades can readily be withdrawn from molds of this material.

Of course the molding material of the invention can also be used with wax and plastic patterns which must be melted and burned out.

After ramming and after pattern removal, the flask is readily removed from the mold and the mold is then placed in a suitable oven and subjected to a temperature in excess of 450°F. for a period of time which will allow the entire mold to reach that temperature or above. Of course the temperature required for the center of the mold to reach 450°F. will depend upon the mold thickness and upon the oven temperature. It is necessary to bake the mold at this temperature or above in order to produce a final irreversible set in the molding material and thus render it hard enough to be handled with ease subsequently.

Also after this baking the mold does not have any noticeable tendency to pick up moisture from the air even after prolonged exposure to a humid atmosphere. It is possible to dry the molds out as fast as the water can be evaporated from the mold surface to prevent the exudation of drops of water. Baking temperatures up to 2500°F. have been used in order to speed up the drying and preheating process without ill effects. The baking time required for the center of the mold to reach 450°F. will vary depending on the cross section. No care need be taken to prevents cracking from heat, since the molding material is of course resistant to heat shock.

If it is desired to pour castings having very thin sections in the mold material of the invention it is commonly considered advisable to preheat the mold to from 1000°F. to 2500°F. before pouring, provided of course such temperatures are suitable in casting the particular alloy.

The molding material of the invention is of such a refractory nature that it is feasible to pour high melting alloys such as steel into such molds when preheated to 1500°F. or above. This refractoriness precludes the need for mold washes which are sometimes used with other materials to prevent the molten metal from "burning in" to the mold.

In addition to its other advantages the mold material of the invention has the advantage of being at one and the same time very strong and refractory and highly resistant to mishandling during preheat and pouring, and sufficiently weak to crack under stresses set up by shrinking of the casting during cooling, so as to prevent hot tears and deformation of the casting.

The strength of the molds being very high in both the green and the baked state, the mold can be quite thin and thus no difficulty will be encountered due to low permeability in the mold wall. Furthermore because of the fineness of the aluminous material of the character of fused alumina, fused silicous alumina or aluminous mullite used and because of the high strength of the molds it is possible to obtain casting with a very
smooth surface and fine detail with a tolerance of a few thousandths of an inch.
All percentages referred to herein are by weight.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the process and composition shown, and I therefore claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A mold composition of the character which is used to produce castings having close tolerance and a fine surface finish and is suitable for casting high melting point alloys containing titanium and aluminum after baking the mold composition to a temperature above 450° F., comprising essentially 85 to 98 percent by weight of particles predominantly through 200 mesh per linear inch of a silicious material containing at least 70 percent of aluminum oxide by weight and selected from the class consisting of fused alumina, fused silicious alumina and alumino-mullite, 15 to 2 percent by weight of a swelling clay and 2 to 10 parts by weight of water added to 100 parts by weight of the dry ingredients.

2. A mold composition for use after admixture with water and baking to a temperature above 450° F. to produce castings having close tolerance and fine surface finish, and capable of casting high melting point alloys containing titanium and aluminum, comprising essentially 85 to 98 percent by weight of particles through 200 mesh per linear inch of an aluminous mineral containing at least 70 percent by weight of aluminum oxide and selected from the class which consists of fused alumina, fused silicious alumina and alumino-mullite and 15 to 2 percent by weight of a swelling clay.

3. A mold composition of the character which is used to produce castings having close tolerance and a fine surface finish and is suitable for casting high melting point alloys containing titanium and aluminum after baking the mold composition to a temperature above 450° F., comprising essentially 85 to 98 percent by weight of particles predominantly through 200 mesh per linear inch of an aluminous mineral containing at least 70 percent by weight of aluminum oxide and selected from the class which consists of fused alumina, fused silicious alumina and alumino-mullite, 15 to 2 percent by weight of bentonite and from 25 to 10 parts by weight of water added to 100 parts by weight of the dry ingredients.

4. A mold composition suitable for use after admixture with water and baking to a temperature above 450° F. to produce castings having close tolerance and fine surface finish, and capable of casting high melting point alloys containing titanium and aluminum, comprising essentially 85 to 98 percent by weight of particles through 200 mesh per linear inch of an aluminous mineral containing at least 70 percent by weight of aluminum oxide and selected from the class consisting of fused alumina, fused silicious alumina, and alumino-mullite, 15 to 2 percent by weight of bentonite and from 25 to 10 parts by weight of water added to 100 parts by weight of the dry ingredients.

5. A mold composition of the character which is used to produce castings having close tolerance and fine surface finish and is suitable for casting high melting point alloys containing titanium and aluminum after baking the mold composition to a temperature above 450° F., comprising 95 to 98 percent by weight of particles predominantly through 200 mesh per linear inch of an aluminous mineral containing at least 70 percent of aluminum oxide and selected from the class consisting of fused alumina, fused silicious alumina and alumino-mullite, 5 to 2 percent by weight of a swelling clay and from 22 to 10 parts by weight of water added to 200 parts by weight of the dry ingredients.

6. A mold composition of the character which is used to produce castings having close tolerance and a fine surface finish and is suitable for casting high melting point alloys containing titanium and aluminum after baking the mold composition to a temperature above 450° F., comprising 95 percent by weight of an aluminous mineral, 85 percent of which is in the form of particles through 200 mesh per linear inch, at least 70 percent by weight of which is aluminum oxide, and selected from the class consisting of fused alumina, fused silicious alumina and alumino-mullite, 5 percent by weight of a swelling clay of the character of bentonite, and 22 percent by weight of water to 100 parts by weight of the dry ingredients.

7. The process of forming a mold of high strength and refractory properties and capable of obtaining close tolerance and fine finish in the casting and also capable of casting high melting point alloys containing titanium and aluminum, which comprises ramming a mixture of 98 to 85 percent of particles of aluminous mineral, 5 percent by weight of which are through 200 mesh, containing in excess of 70 percent by weight of aluminous mineral and selected from the class consisting of fused alumina, fused silicious alumina, and alumino-mullite, from 2 to 15 percent by weight of a swelling clay and 10 to 25 parts by weight of water to 100 parts by weight of the dry ingredients and heat treating the mixture at a temperature in excess of 450° F., whereby the mold material undergoes an irreversible reaction and greatly increases its strength.

References Cited in the file of this patent

UNITED STATES PATENTS

- 2,169,385 Hall Aug. 15, 1939
- 2,380,945 Collins Aug. 7, 1945
- 2,504,133 Kerlin Apr. 18, 1950
- 2,510,120 Grube June 6, 1950
- 2,521,839 Feagin et al. Sept. 12, 1950
- 2,556,814 Greenewald Feb. 26, 1952