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[54] METHOD OF MAKING MOLDS

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[58] **Field of Search** 106/38.3, 38.35, 38.9, 106/38.22, 38.23, 38.24, 38.25

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[57] **ABSTRACT**

A method of making molds for use in casting highly reactive metals such as titanium, zirconium, hafnium, columbium, and alloys thereof in which granular graphite, olivine or mixtures thereof are mixed with a binder such as sodium silicate to form a mixture which is rammed into a flask about a pattern to form a mold. The mold is removed from the pattern with or without first hardening and is then baked at a temperature up to about 290° F. The mold is then coated with a thermally insulative coating which is nonreactive with the molten metal such as alumina in an acrylic binder. The mold is then ready for use or it can be stored indefinitely under conditions which prevent its picking up moisture.

21 Claims, No Drawings

METHOD OF MAKING MOLDS

This invention relates to the making of molds for use in foundry casting and, more particularly, to the making of such molds suitable for use in the casting of highly reactive metals such as titanium, zirconium, hafnium, columbium and alloys containing such reactive metals.

Hitherto, graphite molds have been used in the casting of such reactive metals as titanium and its alloys, but such molds have left much to be desired. Molds machined from graphite have proven to be expensive, even for casting relatively simple shapes, and not at all suited for the casting of the more complex shapes required today. To overcome this, graphite in granular form mixed with a suitable binder is forced, as by ramming, into intimate contact with a suitable pattern and fired at elevated temperatures above about 1000° F. Such firing not only adds significantly to the cost of the molds, but also can result in shrinkage and distortion which interferes with the high degree of precision usually required.

The use of molds as hitherto provided, whether formed by machining from graphite blocks or from granular graphite with a binder has also resulted in surface defects in the cast articles such as flowlines and negative defects which have also added to the cost of the castings.

It is therefore a principal object of this invention to provide an improved method of making foundry molds especially well suited for use in casting reactive metals such as titanium, zirconium, hafnium, columbium and alloys thereof having more or less complex shapes, which permits the use of conventional foundry techniques and equipment, which provides molds capable of enhanced precision and freedom from defects in the parts cast therein, and that can be readily separated from the patterns about which they are formed, and which method is relatively simple and requires less time to carry out.

Further objects as well as advantages of the present invention will be apparent from the following detailed description of preferred embodiments thereof. In carrying out the present invention, a suitable refractory material such as granular graphite, a suitable sand such as olivine, or mixtures thereof are mixed with a suitable binder to provide a mixture having a consistency suitable for ramming. A pattern is placed into a flask, and the prepared refractory and binder mixture is rammed into the flask about the pattern to form the mold to the required shape. The green mold is then separated from the pattern, or if the complexity of the shape is such as to require it, the mold can be hardened as by subjecting it to carbon dioxide gas. After being separated from the pattern, the mold is baked to drive off free water at a temperature above the boiling point of water but not high enough to cause an excessively violent emission of steam which could damage the mold. Following this low temperature bake, the mold is coated with a thermally insulative coating of a material which is nonreactive with the molten metal. The mold is now ready for use or it can be stored under conditions which prevent its picking up free moisture until it is to be used. Casting in molds prepared in accordance with the present invention can be carried out employing conventional foundry techniques. In the casting of titanium and its alloys, centrifugal casting is preferably used.

The refractory material used in preparing the ramming mixture can be granular graphite, mixtures of graphite and a high fusing point sand such as olivine sand, with the graphite forming as little as a minor portion by weight thereof, down to 25 percent or less, or it is contemplated that the graphite could be omitted entirely and the mold formed from the olivine sand and binder alone. Hitherto, molds formed of graphite tended to chill metals such as titanium and its alloys (which are characterized by a relatively narrow liquidus/solidus range). It is an important feature of this invention that the thermally insulating coating which is applied to baked molds in accordance with the present invention not only greatly improves the quality of the castings obtained from molds formed of graphite, but also makes possible the use of large proportions of sand or even the formation of the mold entirely from sand and binder without any graphite. While it is not now fully understood why this is so, it is believed that the beneficial effect of the coating in significantly reducing surface defects in the castings and in making possible the highly successful use of molds containing little graphite results from the effect of the coating in impeding or retarding the transfer of heat across the mold/-metal interface and thus retarding its chilling effect.

The particle size of the refractory material is not at all critical, and suitable particle size distributions range from about 50 to 150 in accordance with the fineness values of the American Foundrymans Society (AFS). In the case of graphite, an AFS fineness number of about 50 to 75 may be used. Olivine sand having an AFS fineness number of about 120 gave good results although a somewhat coarser and more permeable sand having an AFS fineness number of about 70 may also be used.

In forming the ramming mix, the refractory is mixed with a suitable water-soluble binder, preferably sodium silicate which can be used in liquid or powder form. Good results have been obtained using Philadelphia Quartz GD sodium silicate powder. After mulling the graphite and silicate powder, water is added and the whole is then mulled to provide the ramming mixture, which has a working life of about 12–24 hours and preferably is used while fresh.

Electric furnace graphite powder of the desired fineness and with a minimum of ash content has proven to be suitable. For example, Superior Graphite Co. grade 5018 with 2 percent or less ash content or Union Carbide BB5 can be used.

After mulling, the mixture of refractory and binder is ready to be rammed into a flask onto the pattern. Once the mold material has been rammed onto the pattern, the mold is carefully removed in the green state, or if the shape is too complex, it is first hardened by gassing with carbon dioxide gas. After the mold is removed from the pattern whether green or hardened, it is baked at a temperature above 212° F but not higher than about 290° F to complete hardening of the mold and to remove free water. Preferably, baking is carried out at about 250° F for about one hour for each inch of mold material thickness.

Following baking, suitable gates and risers are cut in the usual way and then the mold is provided over its entire working surface with an insulative coating formed of calcined alumina (Al_2O_3) in an acrylic binder. While the particle size of the alumina is not critical, it is preferably about 10 microns. KC8 calcined alumina (alpha phase) from Kaiser Chemicals, Baton Rouge, La., ground to −325 mesh has been used with good results. The alumina powder is mixed with a clear acrylic binder to provide a slurry having a consistency suitable for spraying. The proportions of about one pound alumina to one pint binder have provided good results. The coating can also be applied by painting or dipping. Usually the coating is applied to a thickness of about 0.001 to 0.005 inch. A suitable acrylic binder has been found to be polyethyl or polymethyl methacrylate in a fast vaporizing solvent such as ethylene dichloride. Acryloid No. B82 and No. B72 available from Rohm & Haas Co., Philadelphia, Pa., have both been used with good results.

After application of the coating, the mold is ready for use. If it is not used immediately, the mold can be stored under conditions which prevent pick-up of moisture. Preferably, the mold is stored at a temperature just above the boiling point of water, and about 250° F has proven convenient.

Molds produced in accordance with the present invention provide castings which are characterized by greatly improved freedom from flowlines and other surface defects. These improvements are apparent when such highly reactive metals as titanium and its alloys are cast into shapes in molds formed substantially entirely of graphite as the refractory material. But even better overall results are obtainable when, in accordance with the present invention, graphite forms 50% or less of the refractory material. Reducing the graphite content seems to make possible the use of significantly less binder with the concomitant advantage of a reduction in the amount of volatile material subsequently to be removed before the mold is coated and ready for use.

Conventional foundry techniques are used in pouring and casting the metal in the molds of the present invention, the molten metal being delivered to the mold with sufficient force to expel gases from the metal, across the metal/mold interface, and through the mold wall to its exterior which is maintained under vacuum. Centrifugal casting has provided outstanding results, but because of low mold baking temperature, resulting in incomplete removal of volatiles from the mold, about twice the centrifugal force normally applied when using machined graphite molds should be used. The rotational speed to be used for best results will depend upon the permeability of the mold, mold size and casting thickness, and can be readily determined in practice.

Because of the reactivity of molten metal such as titanium, a very thin surface layer of the casting will pick up some oxygen and carbon, but, when desired, such contaminants can be readily removed by abrasive blasting or by means of a chemical pickling bath. The depth of the contaminated layer may range from about 0.003 to 0.010 inch, depending upon the thickness of the casting.

The following examples further illustrate preferred embodiments of the present invention.

EXAMPLE I

Graphite at about AFS fineness No. 60 and powdered sodium silicate in the proportions of 100 parts by weight graphite and 18 of sodium silicate were mixed in a muller for about 5 minutes. Then 12 parts by weight water was added, and the mixture was mulled for 3 minutes to provide the ramming mixture. After ramming onto the pattern, the green mold was carefully removed and then baked at about 250° F for about 12 hours until the mold was hardened and substantially all free water was driven off. The required gates and risers were cut in the mold, and then it was spray coated to a thickness of about 0.002 inches with a slurry made up of Acryloid No. B82 (Rohm & Haas) in ethylene dichloride as a binder and KC8 calcined alumina (Kaiser Chemicals) ground to pass a 325 mesh sieve, in the proportions of 1 pound of alumina to 1 pint of binder.

Molds thus formed were mounted on a centrifugal casting table with the exterior thereof subjected to a vacuum of about 100 microns. The molten titanium was poured in the usual way but with the 5-foot diameter table rotating at about 300 rpm so as to subject the flowing metal to about a 60g force. The castings obtained in this way were substantially free of flowlines and surface defects. Because of the reactivity of titanium, a surface layer of the casting about 0.003 to 0.010 inch thick picked up oxygen and carbon but this was readily removed by first subjecting the casting to a heavy grit blast and then pickling in a 3 to 5 percent aqueous hydrofluoric acid (HF).

EXAMPLE II

Molds were prepared as was described in connection with Example I except that the ramming mixture was prepared as follows

	Parts by Weight
Graphite AFS No. 60	50
Olivine AFS No. 120	50
Sodium Silicate	10
Water	10

The mold was baked and coated, and titanium castings were made, all as was described in connection with Example I. The resulting castings were also sound and had a surface finish as good as usually obtained in the casting of iron or aluminum employing sand foundry techniques, metals recognized to be much easier to cast than titanium.

While for best results the method of this invention has been described utilizing sodium silicate as the water-soluble binder in preparing the ramming mixture, other water-soluble binders could also be used. For example, it is contemplated that potassium silicate could be used with satisfactory results in making molds for casting members of relatively thin cross-sectional thickness.

The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. The method of making a mold which includes the steps of forming a mixture of (a) a refractory material selected from the group consisting of granular graphite, olivine sand and combinations thereof, (b) a water-soluble binder selected from the group consisting of sodium silicate and potassium silicate, and (c) water, shaping a mold from said mixture, baking said mold at

a temperature above about 212°F but not higher than about 290°F to remove free water, and coating substantially the entire working surface of said mold with a thermally insulative coating about 0.001–0.005 inch thick formed of a fine refractory powder and a binder.

2. The method of making a mold as set forth in claim 1 in which said water-soluble binder is sodium silicate.

3. The method of making a mold as set forth in claim 1 in which said mixture is shaped about a pattern to form a mold, and said mold is removed from said pattern before it is baked.

4. The method of making a mold as set forth in claim 3 in which said mold is hardened before it is removed from said pattern.

5. The method of making a mold as set forth in claim 1 in which said refractory powder is calcined alumina.

6. The method of making a mold as set forth in claim 5 in which said binder of said coating is an acrylic binder.

7. The method of making a mold as set forth in claim 1 in which said refractory material is powdered graphite.

8. The method of making a mold as set forth in claim 1 in which said refractory material is a mixture of powdered graphite and olivine sand.

9. The method of making a mold as set forth in claim 8 in which the particle size of said refractory material ranges from about 50 to 150 AFS.

10. The method of making a mold as set forth in claim 8 in which said refractory material comprises substantially equal amounts by weight of graphite powder and olivine sand.

11. The method of making a mold as set forth in claim 8 in which said refractory material comprises 3 parts by weight olivine sand for each part of graphite powder.

12. The method of making a mold which includes the steps of forming a mixture of powdered graphite, olivine sand and sodium silicate, adding water to and mulling said mixture, shaping a mold from said mulled mixture, baking said mold at a temperature above about 212°F but not higher than about 290°F to remove free water, and coating at least substantially the entire working surface of said baked mold with a thermally insulative coating about 0.001–0.005 inch thick formed of calcined alumina powder and a binder.

13. The method of making a mold as set forth in claim 12 in which said mulled mixture is forced about a pattern to form said mold, and said mold is removed from said pattern prior to baking.

14. The method of making a mold as set forth in claim 13 in which said mold is hardened before it is removed from said pattern.

15. The method of making a mold as set forth in claim 13 in which said insulative coating is formed of calcined alumina powder and an acrylic binder.

16. The method of making a mold as set forth in claim 15 in which said mixture comprises substantially equal parts by weight of powdered graphite and olivine sand.

17. The method of making a mold as set forth in claim 15 in which said mixture comprises substantially 3 parts by weight of olivine sand for each part of graphite powder.

18. The method of making a mold as set forth in claim 12 in which the particle size of said mixture ranges from about 50 to 150 AFS.

19. The method of making a mold as set forth in claim 12 in which the particle size of said powdered graphite ranges from about 50 to 75 AFS, and the particle size of said olivine sand ranges from about 70 to 150.

20. The method of making a mold which includes the steps of forming a mixture of olivine sand and sodium silicate, adding water to and mulling said mixture, shaping a mold from said mulled mixture, baking said mold at a temperature above about 212°F but not higher than about 290°F to remove free water, and coating at least substantially the entire working surface of said baked mold with a thermally insulative coating about 0.001–0.005 inch thick formed of calcined alumina powder and a binder.

21. The method of making a mold which includes the steps of forming a mixture of (a) a refractory material selected from the group consisting of granular graphite, olivine sand and combinations thereof, (b) a water-soluble binder selected from the group consisting of sodium silicate and potassium silicate, and (c) water, shaping a mold from said mixture, baking said mold at a temperature above about 212°F but not higher than about 290°F to remove free water, and coating substantially the entire working surface of said mold with a thermally insulative coating formed of a fine refractory powder and an acrylic binder.

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