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F. X. HOHN ET AL

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MOLD MATERIAL FOR CASTING GROUP IV₆ METALS AND METHOD OF MAKING SAME

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FIG. 1

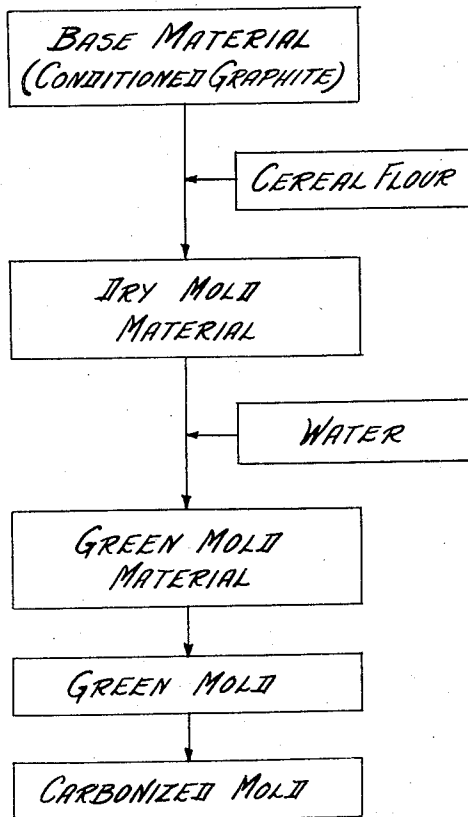


FIG. 2

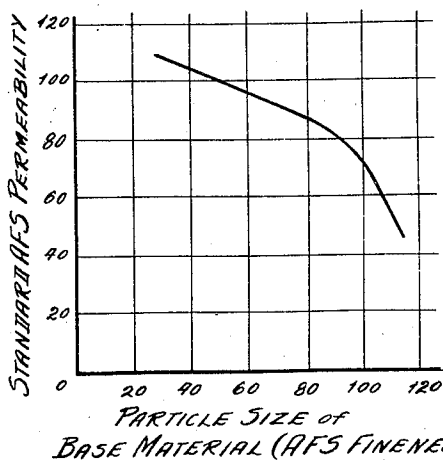


FIG. 3

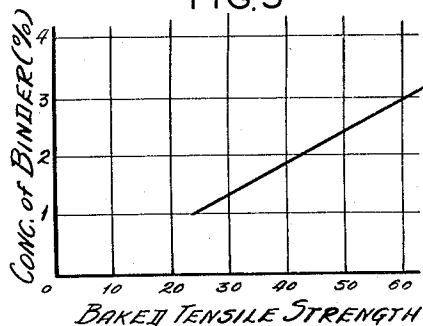


FIG. 4

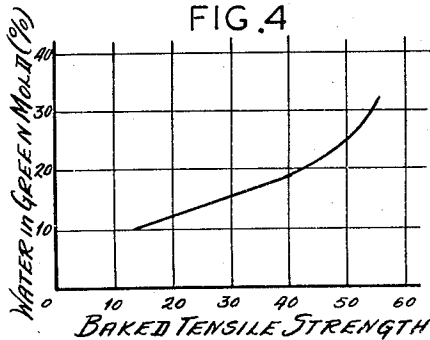
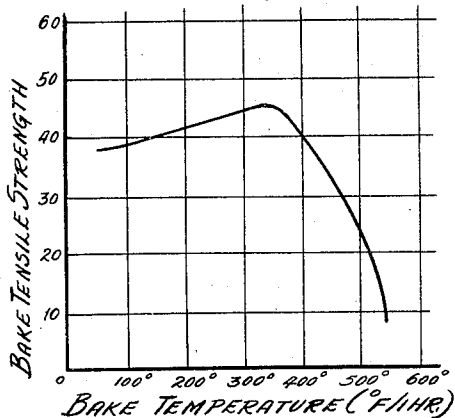


FIG. 5



INVENTORS:

FRANK X. HOHN
FRANCIS H. HOHN

By *Gravelly, Lieder, Woodruff & Wills*
ATTORNEYS.

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MOLD MATERIAL FOR CASTING GROUP IVb METALS AND METHOD OF MAKING SAME

Frank X. Hohn, St. Louis, and Francis H. Hohn, Webster Groves, Mo., assignors, by mesne assignments, to Universal Marion Corporation, Jacksonville, Fla., a corporation of the District of Columbia

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This invention relates generally to metal founding, and more particularly to improvements in mold materials for casting group IVb metals of the periodic system of elements, such as hafnium, thorium, titanium, zirconium and their alloys. The invention also relates to a method of making improved molds for casting group IVb metals. Although the present invention will be disclosed with reference to titanium, it is to be understood that other group IVb metals may be cast in molds embodying the present invention.

Titanium is ideally suited for many types of casings including valves, fittings, structural shapes and the like because of its excellent strength to weight ratio and superior corrosion resistance. Titanium in solid form is a stable element, but when its temperature is raised to the melting point titanium becomes extremely active chemically and combines with most elements, especially oxygen and nitrogen. It is well known that titanium casting techniques have not kept up with the rapid developments in other phases of titanium technology because of this extreme reactivity or chemical affinity between molten titanium and the commonly used molding materials. Suitable castings have been made in extremely thin sections in many types of molds where the chill effect inhibits or prevents a reaction of the mold material with the molten titanium due to the rapid cooling and solidification of the surface of the titanium. However, the chill effect may also have an adverse effect on the surface quality or other characteristics of the casting by causing a wrinkled or uneven surface and by causing solidification of the titanium before the mold cavity is filled. When titanium is cast in conventional refractory oxide and silicate molds, a violent reaction occurs therebetween resulting in a porous, embrittled mass. In the past, research has shown that permanent molds machined from solid graphite were practically inert to molten titanium, but these molds are expensive to make, often cause chill effects on the surface of the castings and crack or spall after a few castings have been made therein. Other research has shown that molds formed of refractory materials, such as silica and zirconia sands coated with graphitic washes or other chemical agents, have also been unsatisfactory due to buckling and spalling of the coating or the penetration of the coating by the titanium. A resin bonded graphitic shell mold has been used to produce titanium castings in extremely thin sections where the chill effect prevents mold reaction with the molten titanium. However, in larger castings resin bonded graphitic molds have also been unsatisfactory. An ideal mold material for titanium should be inexpensive, easy to form into molds and inert to molten titanium but none has been known, heretofore.

The principal object of the present invention is to provide an expendable mold material that will not react with molten titanium to any appreciable extent, and which can be formed into molds by employing standard foundry molding methods. More particularly, it is an object to provide a bonded, granular, flowable material that can be rammed, blown, squeezed or jolted around a pattern, and which will have a dimensionally accurate mold cavity when the pattern is withdrawn.

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Another object is to provide a mold material that can be cured to the desired hardness and permeability so that molten titanium can be cast to a dimensionally accurate shape.

Still another object of the present invention is to provide a novel mold material that is substantially inert to molten titanium whereby the reaction therebetween will be eliminated or reduced to a minimum.

A still further object is to provide an economically produced, expendable material which can be molded and reduced to a substantially complete carbonaceous mold for casting molten titanium, and in the provision of a method for forming the mold.

Another object is to provide a mold material that can be conditioned repeatedly for reuse in making molds for casting titanium.

Another object is to provide a mold material that can be employed as a facing backed by conventional mold materials to form molds that are suitable for casting molten titanium.

These and other objects and advantages will become apparent hereinafter.

Briefly, the present invention is embodied in a mold material including granular graphite as a base, and a carbonizable material as a binder. The invention also includes and method of making molds and in the molds made by said method.

In the accompanying drawings which form a part of this specification;

Fig. 1 is a flow diagram illustrating the steps in a method of making molds embodying the present invention,

Fig. 2 is a graphic illustration showing the effect of varying the particle size of the base material on the permeability of the mold material,

Fig. 3 is a graphic illustration showing the effect of varying the concentration of binder material on the baked tensile strength of the mold,

Fig. 4 is a graphic illustration showing the effect of varying the water content in the green mold on the baked tensile strength of the mold, and

Fig. 5 is a graphic illustration showing the effect of varying the baking temperature on the baked tensile strength of the mold.

Advances in titanium technology have provided suitable methods and apparatus for the reduction of titanium compounds to substantially pure titanium, for melting titanium without introducing impurities and for alloying other metals with titanium. However, heretofore no suitable method or apparatus has been provided for molding titanium and titanium alloys so that a substantially uncontaminated casting is provided. Because of the extreme chemical affinity of titanium for the usual mold materials, most titanium castings produced in the past have had embrittled, pitted surfaces reducing the ductility and machinability of the casting. This is true of granular graphite bonded by resins or the like, and machined graphite is the only mold that has been known to provide substantially uncontaminated castings. However, machined graphite molds are impractical because of the initial expense and comparatively short life thereof due to cracking and spalling.

The present invention provides a mold material formed of granular graphite bonded by a suitable carbohydrate or cellulosic material. This material is formed into a green mold which is then cured by carbonization to reduce to a minimum gas evolution during casting. The titanium castings produced in molds embodying the present invention are substantially free from contamination, and it is apparent that the present mold material provides all of the advantages of machined graphite molds without having any of the disadvantages thereof. The

present molds are produced by the application of conventional mass production foundry practices and so economically that they are expendable compared with previously known titanium molds, such as machined graphite. Furthermore, although the present mold is expendable, the material may be conditioned for reuse if desired.

The present mold material comprises a base of granular graphite, which preferably has an 89 fineness particle size (as determined by A. F. S. Standard Screen Analysis), such a graphite being sold by National Carbon Company under code number GPBB4P9. Of course, any granular graphite having a similar grain size distribution may be used, but flake graphite is not suitable. Furthermore, the fineness of the graphite may be varied within predetermined limits, as will become apparent hereinafter. It is, of course, well known that graphite is one form of the element carbon which varies from other forms (amorphous carbon and diamond) in the physical property of density. Reference to graphite herein has been made for the purpose of noting one form of carbon, and amorphous carbon is included within the scope of the present invention.

According to the present invention, a cereal flour is employed as a binder for bonding the granules of graphite together. Although other cereal flours or materials which can be reduced to a carbonaceous state may be used, either corn flour or corn starch that has been pre-gelatinized is presently preferred as the binder. The amount of binder used may also be varied within predetermined limits to be more fully set out.

To provide an intimate mixture between the base and binder materials, a predetermined amount of water is added. The method of making molds will now be described in detail so that the characteristics and advantages of the mold material and method will become readily apparent.

Before the granular graphite can be used in making the mold material, it should be conditioned to assure that substantially all volatiles are removed therefrom. Therefore, the graphite is baked at 800° F. for approximately 1 hour to remove these gases. If the material is lumpy, it should be milled for a brief period of time in a suitable apparatus to break up these lumps. Extended mulling should be avoided because of the reduction in granule size resulting in a mold mixture having a greatly reduced permeability.

When the graphite base material is conditioned, the cereal flour binder is added and milled with the base material to assure that each of the graphite grains is uniformly coated or covered with the binder material.

Water is added to the dry mixture of cereal flour and graphite, and the aqueous mixture is milled to obtain the desired surface wetting characteristics for cohesion of the particles. The graphite grains do not break up as rapidly during wet mulling, but prolonged mulling in this stage will result in matting or clumping of the mixture.

The mixture is now prepared for making a mold and, because the material must be cured, it is designated as green mold material in Fig. 1 and the mold prior to curing is referred to as a green mold. The mixture is formed about a mold pattern according to present foundry practices in making conventional sand molds, and the pattern is drawn. Inasmuch as one of the purposes of the invention is to provide an expendable mold in which titanium castings may be made without contamination, the mold may comprise a facing of suitable thickness of the green mold material backed up by another molding material. The thickness of the facing is predetermined so that no reaction will occur between the titanium and the backing material. However, whether the green mold is formed entirely of green mold material or comprises a facing of the material backed by another mold material, the same curing procedure is used.

Curing of the green mold comprises two operations; namely, drying and baking or carbonizing. Drying is necessary to remove substantially all of the water from the green mold, and preferably is done at room temperature for an extended time, such as 24 hours, or the green mold can also be maintained at a low even temperature for shorter periods of time, such as 200° F. for about 8 hours. Drying must be done slowly to prevent distortion of the mold cavity by the too rapid evolution of steam.

The final step in curing the green mold is baking the mold to carbonize the binder whereby a substantially carbonaceous mold is provided. This step is the most critical inasmuch as a large portion of the volatiles must be removed from the mold, and yet the strength of the carbonized mold must be as high as possible. Carbonization is conducted at 450° F. for a suitable period of time depending upon the mold thickness. For example, 1 hour is found preferable for a one inch thick section.

It is now apparent that the method of forming carbonaceous molds for making titanium castings comprises the steps of conditioning the graphitic base material, adding and mulling the binder therewith, adding and mulling water with the dry mixture of base and binder materials to form green mold material, forming the material into a green mold, and curing the green mold by drying and carbonizing.

In making the mold material, certain proportions of the components are presently preferred for making most molds for casting titanium and its alloys. However, it is to be understood that variations in characteristics and concentrations of the components may be effected to obtain special effects or to compensate for other factors entering into the formula. As set out previously, the granular graphite preferably has a fineness number of about 89. Referring to Fig. 2, it will be seen that the particle size is an important factor in determining the permeability of the mold material. Therefore, fineness has been controlled to provide the mold with the best combination of permeability and minimum metal penetration. Removal of the finer granules of graphite increases both the permeability and the strength of the carbonized mold appreciably, but reduction of the A. F. S. fineness number increases the danger of penetration of the mold by molten titanium. Therefore, the A. F. S. fineness number of the graphite should not be below approximately 50.

Referring to Fig. 3, it will be seen that an increase in the proportion of corn flour (which is preferred as a binder) provides an increased mold strength or hardness. However, increasing the percentage of corn flour also increases the gas evolution and the possibility of contaminating the titanium casting. Therefore, 2.1% of corn flour (by weight) provides the proportion presently preferred, although a range of 1.0% to 3.5% of corn flour has been found to be satisfactory. Corn flour is preferred because of its excellent bonding properties when carbonized to a great extent. Pre-gelatinized corn starch is another preferred binder material that is used in substantially the same proportions as corn flour.

Referring to Fig. 4, about 21.5% of water (by weight) is recommended, but the amount may be varied between 12% and 25%. Graphite grains are porous and a large amount of water as compared to conventional foundry sand mixes is required to obtain a suitable mixture. Increasing the amount of water used reduces the permeability of the mold without affecting the green strength appreciably. An increase in the baked strength of mold also results by increasing the amount of water, but the mold mixture is less flowable and more difficult to mold. Conversely, a decrease in the amount of water reduces the baked strength of the mold.

When a mold having a facing of green mold material backed up with other mold material is made, the thickness of the facing may vary between ½ and 6 inches depending on the size of the casting. If castings are to be

made in complex patterns having both thick and thin sections, the facing thickness may be varied, but ordinarily the facing is of substantially uniform thickness determined by the thick or large sections of the casting. If desired, the backing material may be a conventional molding sand mix or a graphitic molding material having a relatively large particle size distribution may be provided to form a permeability gradient from the interior to the exterior of the mold.

As stated hereinbefore, the carbonization of the green mold is the most critical stage in the process inasmuch as a proper balance of strength and carbonization must be obtained to provide uncontaminated titanium castings. As shown in Fig. 5, 350° is the ideal baking temperature for obtaining maximum strength, however, most binder materials are not sufficiently carbonized at this temperature. Accordingly, 450° is preferred as the temperature for obtaining the best balance between strength and carbonization for corn flour, but the temperature may be varied between 350° and 550° for other materials or to obtain special effects.

In using molds embodying the present invention, titanium may be melted in any suitable furnace (not shown) that is designed to prevent contamination of the molten metal, such as any of the known furnaces. The mold (while still hot from the carbonizing step) is mounted in the furnace in any suitable manner, and the furnace and mold are sealed from the atmosphere. Mold heaters may be used if desired to raise the mold temperature. The furnace and mold are then evacuated prior to pouring or the evacuated furnace and mold may be provided with an inert atmosphere to prevent the chemical reaction of the titanium with oxygen and nitrogen of the air. After the pour, the mold is cooled to a point where the titanium will no longer react with the atmosphere.

Although the present carbonaceous molds are economically made, they do not have to be thrown away after use inasmuch as the graphite may be reconditioned for use in making other carbonaceous molds. The graphite is reconditioned by baking at a temperature between 600° F. and 1200° F., whereby the binder material will be substantially burned out and only the granular graphite will be left. The reconditioned graphite may be screened to remove accumulated fines if necessary and is then ready for forming molds according to the process described.

It is now apparent that a carbonaceous, expendable mold has been provided for casting titanium without appreciable contamination, and the process for making the mold is simple and effective. The foregoing description has been given only by way of illustration and example, and changes and modifications in the components and the percentages thereof for the mold material and in the method of making the same, which will be apparent to all those skilled in the art, are contemplated as within the spirit and scope of the present invention, which is limited only by the claims that follow.

What we claim is:

1. A green mold material for making molds in which group IVb metals may be cast without substantial contamination, consisting essentially of granular graphite, about 1.0% to 3.5%, by weight, of a corn flour derivative, and sufficient water to wet the graphite and corn flour derivative.

2. A green mold material for making molds in which group IVb metals may be cast without substantial contamination, consisting essentially of granular graphite, about 2.1%, by weight, of a corn flour derivative, and sufficient water to wet the graphite and corn flour derivative.

3. A green mold material for making molds for group IVb metal castings, consisting of granular graphite; about 1.0% to 3.5%, by weight, of a corn flour derivative; and about 12% to 25%, by weight, of water.

4. A green mold material for making molds for group

IVb metal castings, consisting of granular graphite, about 2.1%, by weight, of a corn flour derivative, and about 21.5%, by weight, of water.

5. A cured mold for making group IVb metal castings comprising a substantially non-reactive facing consisting essentially of a granular graphite base and a carbonized binder of a corn flour derivative, said facing having a substantially uniform thickness of between ½ and 6 inches, and a backing of other mold material.

6. A dried mold adapted to be carbonized for making group IVb metal castings comprising a facing consisting essentially of about 95.8% to 98.9%, by weight, of granular graphite as a base and about 4.2% to 1.1%, by weight, of carbonizable corn flour derivative as a binder, the permeability of said facing being predetermined, and a backing of other mold material having a greater permeability than said facing.

7. The method of preparing granular graphite for re-use as a base material in forming a substantially inert mold in which the graphite granules are bonded together with a corn flour derivative, including the steps of baking the graphite at a temperature between 600° F. and 1200° F. for a predetermined time, and screening accumulated graphite fines from the residue to provide granular graphite having a predetermined particle size.

8. A green mold material adapted to be formed into molds and cured to a substantially carbon state for casting reactive metals therein, said mold material consisting essentially of about 87% to 71.5%, by weight, of granular graphite, about 1% to 3.5%, by weight, of a corn flour derivative, and about 12% to 25%, by weight, of water.

9. A green mold material adapted to be formed into molds and cured to a substantially carbon state for casting reactive metals therein, said mold material consisting of about 76.4%, by weight, of granular graphite, about 2.1%, by weight, of a corn flour derivative, and about 21.5%, by weight, of water.

10. A dried metal founding mold adapted to be carbonized to remove gaseous matter therefrom for casting reactive metals without substantial contamination, consisting essentially of about 95.8% to 98.9%, by weight, of granular graphite, and about 4.2% to 1.1%, by weight, of a corn flour derivative.

11. A dried metal founding mold adapted to be heated at controlled temperatures to a cured condition in which gaseous matter is removed therefrom to provide an essentially carbon mold in which reactive metals may be cast without substantial contamination, consisting essentially of about 95.8% to 98.9%, by weight, of granular graphite having a particle fineness of about 89 by AFS Standard Screen Analysis, and about 4.2% to 1.1%, by weight, of a corn flour derivative, said granular graphite forming the base material of the mold and said corn flour derivative binding the graphite granules together in both the dried and the cured condition of the mold.

References Cited in the file of this patent

UNITED STATES PATENTS

1,218,394	Danloy	Mar. 6, 1917
1,319,151	Gilligan	Oct. 21, 1919
1,346,333	Petiot	July 13, 1920
1,871,315	Gann	Aug. 9, 1932
1,886,252	Gann	Nov. 1, 1932
1,901,124	Saeger	Mar. 14, 1933
2,197,660	Glunz et al.	Apr. 16, 1940
2,422,118	Meyer	June 10, 1947
2,491,096	Feagin	Dec. 13, 1949
2,507,082	Allison	May 9, 1950
2,725,302	Ederer	Nov. 29, 1955

FOREIGN PATENTS

575,693	Great Britain	Feb. 28, 1946
511,794	Canada	May 4, 1949