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COATED MOLD AND METHOD OF COATING SAME

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This invention relates to the art of casting and is concerned more particularly with a multi-layer coating adapted to protect permanent molds used in casting metal shapes.

In the prior art to which this invention relates, it is already known to protect the surfaces of permanent molds with replaceable refractory shells. It has also been suggested to protect the surfaces of such molds from attack by molten metal by forming on the heated mold surfaces a refractory and heat-insulating layer. These layers are normally composed of fire clays or refractory materials admixed with various binders, such as aqueous sodium silicate or aluminum chloride.

Generally speaking, all presently available coatings require considerable maintenance to avoid detracting from the surface finish on the castings when normal chipping and spalling occurs in the coating. To avoid this maintenance cost, most manufacturers sacrifice mold life by producing castings from uncoated molds. Rapid deterioration of the mold surface, through erosion and heat checking, again produces castings which have poor finish or require excessive cleaning costs.

With a view to overcoming the above-outlined disadvantages of the prior art, the main object of the present invention is to protect the mold surfaces of permanent molds from attack by molten metal. This invention is not limited to the production of castings in the iron based alloys, but is also applicable to the production of copper or aluminum alloys, since the novel features of adherence and insulation can also benefit foundry production of castings from these metals.

A further object of this invention is to provide a long-lasting coating which is metallurgically bonded and fused to a permanent mold.

An equally important object of the invention is to provide a multi-layer coating for permanent molds, which coating results in a good surface finish in the castings produced with the aid thereof.

An additional object of the invention is to produce a coating for permanent molds, which coating has superior insulating properties so as to make possible the production of very thin walled and intricate shapes.

Another object of this invention is to provide a casting method using the novel coating herein disclosed to produce commercially uniform and acceptable castings. This can be promoted by designing the coating thicknesses to advance or retard the rates of solidification of metal. Drastic differences in cooling rate between widely different casting thicknesses can be balanced by adjusting coating parameters.

Yet another object of the invention is to provide a multi-layer protection coating for permanent molds which will permit the production of castings of unusually low section thickness with a very high yield of good casting weight to weight of metal poured.

The claimed invention, whereby the foregoing objects are attained, comprises planing the mold surfaces to be coated, applying on the surfaces of the mold which are to be contacted by molten casting metal, a first coating composed of a relatively high conductivity, high ductility metal or alloy metallurgically bonded to the substrate; superimposing on this base coating at least one bonded

coating composed of a blend made up of the material used in the base coating and an inert refractory oxide; and finally applying a fusion bonded overlay composed of one or more refractory oxides.

In the practice of the invention, the faces of the male and female dies forming the mold are first planed, preferably by grit or shot blasting, to provide a surface free from excessive oxidation or foreign matter. During this cleaning operation, the surfaces of the mold are somewhat roughened by the cleaning operation. This technique is recognized by those skilled in the deposition of plasma spray coatings to assist bond strength by contributing a surface which provides mechanical locking as well as the desired metallurgical bond.

The base layer of the claimed multi-layer coating should have a thickness of at least 0.003 inch. A preferred material for the base layer is copper metal, to which an addition of aluminum may be made to retard oxidation. Other materials which are acceptable for this purpose include a nickel-aluminum alloy marketed by Metco, Inc., as Powder #404. This latter material cannot be classed as being a high conductivity, ductile material, except when compared to refractory oxides. By properly applying this base coating by plasma spraying, there is produced a high density coating which is metallurgically bonded to the mold surfaces. The techniques of plasma spraying are well known to those skilled in the art to which this invention relates. A number of standard plasma spray units can be used to apply the claimed coatings. These include the "S-Series" of systems by the Plasmodyne Corporation, a Division of Giannine Scientific Corp. of Santa Ana, Calif., and the Metco (Westbury, L.I.), "2M" Plasma Flame Spray system.

The intermediate layers of the claimed coating also are preferably applied by means of a plasma spray in order to achieve a metallurgical bond to the base coat. As used herein, the term "metallurgical bond" signifies a type of bond holding together the atoms of a metal. Such bonding normally results when each of the atoms of the metal contribute its valence electrons to the formation of an "electron cloud" that prevades the solid metal. Metallurgical bonds are characterized by good conduction of heat and electricity and a ductile behavior under stress. The composition of the blended layers can range from 10 to 90 percent of the ductile material used to form the base layer, with the balance being one or more inert refractory oxides from the group of aluminum oxide, zirconium oxide, titanium oxide, silicon dioxide and tin oxide. A preferred formulation for the blend coating, if only one is used, is about 50 percent by weight of the metal and about 50 percent by weight of the oxide or oxides.

The overlayer forming the top layer of the claimed coating is applied by plasma spraying one or more of the above mentioned oxides. A suitable thickness for this layer is 0.003 inch, or more. Again, the technique of application is adjusted so that the refractory overlayer is fusion bonded to the refractory particles in the intermediate layer or layers.

The components of the various layers are applied in the form of powders having a particle size ranging from 15 microns to —150 screen. The multi-layer coating of the invention possesses a combination of metallurgical bonding between the substrate, base coat, and metal in the intermediate coats; and a mechanical lock between the admixed layer of refractory oxide and metal; and a fusion chemical bond between the refractory overlayer and refractory particles in the admixed layer. The superior adherence of the coating is due in part to the strength of bonds attained, and is also due to the use of blends which minimize differences in coefficients of expansion and contraction between metals and refractory

compounds. Shear stresses usually responsible for failure of coatings are minimized by distribution over a much larger area than is normally possible. All the layers can be formed of different thicknesses in order to produce varying effects, such as a higher or lower degree of insulation to achieve specific cooling rates in various areas of the mold or in the castings produced therein.

Before and during the operation of plasma spraying, the substrate is preheated to a moderately high temperature. This temperature is dependent upon the choice of substrate material, and is governed by the rate of oxide formation on the surface of the substrate. Formation of oxides have been recognized to prevent the development of a metallurgical bond and detract from the coating adherence. Optimum preheat temperatures should be above or near the normal operating temperatures of the coating system, since this will generate beneficial compressive stresses which resist tensile failure during operation. This preheat can, under certain conditions, be generated by the plasma flame itself and can be shielded from oxidation by the neutral or reducing atmosphere of the flame.

The claimed coating can be formed on molds of various fabrication including cast iron, steel, copper, and bronze. The actual coating thicknesses and blend composition of the intermediate layers, is best determined by those skilled in the art by considering the conditions of the casting operation, the choice of substrate, the composition of the casting metal, and the degree of heat insulation technologically required.

Examples of the coating of the invention are the following:

Mold Substrate	Base Layer	Intermediate	Overlayer
Cast iron	Copper (.009")	{50% Al_2O_3 (.006") / 50% Cu}	Al_2O_3 (.007").
Steel	Copper (.010")	{50% Al_2O_3 (.007") / 50% Cu}	Al_2O_3 (.008").
Cast iron	NiAl (.005")	{50% ZrO_2 (.007") / 50% NiAl}	ZrO_2 (.005").
Steel	NiAl (.004")	{50% ZrO_2 (.006") / 50% NiAl}	ZrO_2 (.005").

The coatings of the invention are used at mold temperatures of 400–1300° F., depending upon metal poured into the molds. With iron, an average temperature of 2500° F. has produced castings with wall thicknesses as low as .050". The coatings have been used to produce self-annealed castings, particularly those of gray iron. In this operation, the metal is poured at temperatures in excess of 2200° F., the castings being withdrawn from the mold immediately after solidification and metal is poured therein again. Metal poured at such temperatures produces service conditions severe enough to cause the previously used coatings to flake, decompose, volatilize or wash off. By contrast, as many as 100 castings have been made with the present castings without evidence of breakdown or failure.

The coatings of this invention may, if desired, be used in conjunction with and coated with carbon or acetylene smoke. The smoke coating provides a reducing atmosphere in the mold and thus retard the development of oxides and slag inclusions in the coatings.

What is claimed is:

1. A multi-layer protection coating for permanent molds comprising a dense base layer of a high ductility, high conductive material metallurgically bonded to the mold surfaces, at least one intermediate layer superimposed thereover and metallurgically bonded thereto and consisting of a mixture of the material composing said base layer and an inert refractory metal oxide, and a refractory overlayer superimposed over said intermediate layer and bonded thereto by fusion bonding and by the joining of like particles in the respective layers.

2. The coating of claim **1**, wherein said base layer has a thickness of at least 0.003 inch, while the intermediate layers have a total thickness of at least 0.003 inch and said overlay has a thickness of at least 0.003 inch.

3. The coating of claim **1**, wherein all layers are of different thicknesses to produce varying effects, such as a higher or lower degree of insulation, for the purpose of achieving specific cooling rates in various areas of the mold.

4. The coating of claim **1**, wherein said intermediate layer is composed of about 50 percent by weight of said high ductility, high conductivity material and of about 50 percent by weight of said oxide.

5. The process which comprises applying a high ductility, conductive base layer on a mold surface, superimposing thereon at least one intermediate layer consisting of a blend of the material forming the base layer with a refractory metal oxide coating, and superimposing an overlay composed of a refractory metal oxide.

6. The process of claim **5**, wherein said layers are formed of different thicknesses.

7. The process of making ferrous castings comprising applying on the surfaces of a permanent mold a base layer of high ductility, high conductivity material, superimposing on said base layer at least one intermediate layer composed of a blend of said first material, and an inert refractory metal oxide and an overlayer of a refractory metal oxide, then pouring molten iron at a temperature of at least 2200° F.; removing the cast article and again pouring iron therein.

8. The process of claim **7**, wherein said layers are of different thicknesses.

9. The process of claim **7**, wherein a smoke coating is applied to cover the refractory metal oxide mold surfaces to provide a reducing atmosphere.

10. The process of making nonferrous castings comprising applying on the surfaces of a permanent mold a base layer of high ductility, high conductivity material, superimposing thereon at least one intermediate layer composed of a blend of said first material and an inert refractory metal oxide and then an overlayer of a refractory metal oxide, then pouring molten metal at a temperature at least sufficient to permit filling the mold; removing the cast article and again pouring metal therein.

11. The process of claim **10**, wherein a smoke coating is applied to cover the overlay of the refractory metal oxide.

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