United States Patent Office

3,509,936
Patented May 5, 1970

3,509,936

COATED ARTICLES AND METHOD OF REDUCING THE EROSION OF INGOT MOLD STOOLS

Joseph B. Kearfott, Lincoln Park, and Charles E. Baer, Jr., Birmingham, Mich., assignors, by direct and mesne assignments, to Nalco Chemical Company, Chicago, Ill.

No Drawing. Filed Feb. 28, 1964, Ser. No. 348,263
Int. Cl. B22c 3/00
U.S. Cl. 164—72 19 Claims

ABSTRACT OF THE DISCLOSURE

The base member or stool of a metal mold used to cast ingots is coated with a coating comprising a vitreous or fused silica refractory material suspended in a colloidal silica sol binder. The coating after being dried adheres to the base member and forms a protective coating which inhibits erosion of the base member while preventing sticking of the ingots to the base member upon ingot formation and permitting removal of the ingots from the molds without inclusions of the coating material.

The present invention relates to a novel coating composition and heat resistant articles coated therewith. In some of its more specific aspects, the invention further relates to the production of ingots from molten steel, and more particularly to a novel method of reducing the erosion of ingot mold stools.

The invention will be illustrated and described hereinafter with reference to a method of reducing the erosion of ingot mold stools. However, it is understood that the novel coating composition of the invention may be used for coating a wide variety of other types of metallic or nonmetallic heat resistant substrates to provide the resulting erosion resistant coated articles.

Following the completion of the refining operation in an open hearth furnace for the production of steel or in a Bessemer converter or electric furnace, the molten steel is tapped from the furnace into a ladle. From the ladle, the molten steel is poured or "teemed" into a series of molds of the desired dimensions for the production of the required shape and size of ingot. The molten steel is allowed to solidify in whole or in part and then the molds are stripped from the resulting ingots. The ingots thus produced are placed in a soaking pit to allow them to reach thermal equilibrium and to conserve the heat of the ingot.

Ordinarily, the ingot molds into which the molten steel is teemed are made of cast iron. A common type of ingot mold for steel mill practice will produce an ingot about two feet thick and about seven feet long. The corners of the mold are rounded and the mold wall is corrugated. The sides are tapered to facilitate stripping of the mold from the ingot. The molds are open at both ends, and when they are ready for teeming, they rest big-end-down on heavy cast iron plates called "stools." A stool may support one or a plurality of molds and may be mounted on a small narrow gage car or "buggy" for ease of movement.

After teeming, the mold, ingot and mold stool on the buggy pass to the stripper after a period of time sufficient to permit a substantial shell of solidified steel to form on all six surfaces of the ingot. The stripper is an overhead crane from which is suspended a vertical arm with jaws that engage lugs cast on the outside of the mold on either side of the mold near the top. Operating between the jaws is a ram or plunger that exerts pressure on the top of the ingot to hold the ingot down while the jaws engage the lugs and exert an upward pull on the mold. The ingot is thus left on the stool as the mold is stripped from it. The ingot is then removed from the stool and the stools move to the stool shed for cleaning and storage prior to reuse.

The prior art practices for producing ingots by the use of ingot mold stools is attended by a number of difficulties. For example, the molten steel teeming down upon the stool tends to erode the stool and cause the stool to dish and eventually drill through. This problem is not encountered in connection with the mold itself, as the impact of the teeming metal is not applied to the mold.

The teeming of the molten steel against the stool and the resulting erosion also tends to cause the teemed steel and the stool to weld together, so that in some instances the ingot is welded integrally to the stool and thus becomes what is known in the art as a "stool sticker." The axial thrust of the ram and the stripper relative to each other are not available to separate the stool from the ingot as in the case of separating the mold from the ingot, and it may be that the downward pressure of the ram against the ingot increases the proportion of stool stickers. In any event, the efficiency of the teeming operation is at least to some extent inversely proportional to the number of stool stickers produced.

In accordance with one important variant of the present invention, it has been discovered that erosion of ingot mold stools can be greatly reduced and stool stickers virtually eliminated by the application to the upper surfaces of ingot mold stools of a special coating. As a result of the application of this coating, it has been found that erosion of the mold stool from teemed steel is so reduced that stools now fail not by drilling through, but rather from other causes unrelated to erosion. Another unexpected result of the present invention is that shapes, sheets and other products produced from cropped blooms, billets or slabs resulting from ingots teemed against a coating of the present invention, are free from detectable inclusions of the coating material. The erosion resistance of the coating of the present invention apparently is also effective to prevent welding of the cooled ingot to the mold stool, so that stool stickers are substantially eliminated.

It is an object of the invention to provide a novel coating composition which is useful in applying erosion resistant coatings on heat resistant substrates.

It is a further object to provide erosion resistant articles which have been coated with the coating composition of the invention.

It is still a further object to provide a method of reducing the erosion of ingot mold stools under impact of teemed molten metal.

It is still a further object to provide a method of protectively coating ingot mold stools without introducing any of the coating material into the useful body of the ingot produced by teeming.

It is still a further object to provide a method of reducing stool stickers in metal teeming and casting practices.

Still other objects and advantages of the present invention will become apparent from a consideration of the following description and the specific example.

The coating composition of the present invention consists essentially of a liquid dispersion of pulverulent fused silica and colloidal silica. The colloidal silica is present in the liquid dispersion in an amount effective to bind the pulverulent fused silica into a coherent coating when the composition is applied and dried as described herein. For example, the liquid dispersion may contain a ratio by weight on a dry solids basis of colloidal silica to pulverulent fused silica of about 1:5 to 1:1, and preferably about 1:4 to 1:2. Best results are obtained in most instances when the above ratio is about 15:50.

The pulverulent fused silica or silica flour is preferably in a very finely divided condition. It may have, for example, a particle size range such that substantially all passes a 200 mesh screen, and for best results about 75% by weight should pass a 325 mesh screen and at least about 30% by weight should have a particle size less than 10 microns in diameter. It should be stressed that the pulverulent fused silica or silica flour is not merely ground naturally occurring silica as in the case of ground sand. Sand and other naturally occurring silica is crystalline and, by contrast, the pulverulent fused silica of the present invention has been fused and cooled to produce a noncrystalline or amorphous silica product, and is in effect a super-cooled liquid that has been subdivided to the desired fine particle size.

The colloidal silica is of such small particle size, preferably in the range of 5–150 millimicrons, more preferably in the range of 5–30 millimicrons, and most preferably of an average size range of 11–16 millimicrons, that it remains in suspension in aqueous media. Colloidal silica aquasols are well known and their preparation is disclosed in numerous patents, including United States Pats. 2,574,902, 2,577,485, 2,750,345 and 3,013,898. Low alkali metal contents may be present such as 0.5–1% or less by weight on a dry solids basis. Preferably the colloidal silica is present in the coating composition of the invention in a quantity effective to serve as a binder for the pulverulent fused silica when dry in the resulting coating. In this connection, it should be noted that dried colloidal silica alone does not provide a suitable coating for heat resistant substrates and especially mold stools as it has a tendency to give rise to inclusions of the silica coating in the usable part of the ingot, perhaps due to erosion of the silica coating during teeming. On the other hand, pulverulent fused silica alone is unsuitable as a coating because it must be applied at a temperature sufficiently high to fuse, which makes it impractical for use as a coating for ingot mold stools and other types of heat resistant substrates.

The liquid content of the coating composition may be, for example, water, a volatile organic solvent, mixtures of volatile organic solvents, mixtures of water and water soluble organic solvents, etc. Examples of organic solvents include normally liquid hydrocarbons, halogenated hydrocarbons, alcohols, ketones, and the like, and especially normally liquid organic solvents containing 1–8 and preferably 1–4 carbon atoms. Water is usually preferred; however, other substances which do not have an adverse effect may be present including stabilizing agents for the dispersion, or antifreeze agents such as ethylene glycol, methyl alcohol, ethyl alcohol, propyl or isopropyl alcohol, etc. The liquid may be present in an amount to provide a desired fluidity which may vary somewhat depending upon the method by which the liquid dispersion is to be applied. When the liquid dispersion is applied by spraying, preferably it should be as thick as can be sprayed readily and the liquid may be present in approximately the minimum amount providing a sprayable consistency.

When pulverulent fused silica and colloidal silica are admixed in liquid dispersion, the resulting dispersion may be applied as a coating layer to a desired heat resistant substrate such as the upper surface of an ingot mold stool to thereby produce a silica coating thereon upon drying. The coating composition may be applied to a metallic mold stool surface at any surface temperature ordinarily encountered in stool shed practice, including even ambient atmospheric temperature. In practice, the mold stools usually are reused sufficiently promptly after cleaning that they are at a somewhat elevated temperature at the time of application of the coating composition of the present invention. If desired, the coating composition may be applied to heat resistant substrates at high surface temperatures such as about 400–1000° F.

The coating of the present invention is applied in the form of a liquid dispersion by any of the conventional coating methods, such as spraying, roller coating, painting, or the like. Spray coating is often preferred. It is also preferable in most instances that the coating be renewed or at least touched up after each use of the mold stool or other silica coated articles.

The coating may be applied on a desired heat resistant substrate such as a mold stool to a thickness of, for example, about 1/32 to 3/4 of an inch, and preferably to a thickness of about 1/16 to 1/8 inch. After application of the coating composition, it is not necessary to treat the resulting coating in any way as it air dries to a hard white silica coating. If the stool is warm, the drying is hastened.

It is important also to note that the coating of the present invention is preferably applied only to the portion of the mold stool contacted by the molten metal and not to the side walls of the ingot mold. In this way, inclusions of the coating material in the finished product are reduced or eliminated.

To enable those skilled in this art to practice the present invention, the following illustrative example is given:

Fifty pounds of high purity fused silica powder of 100%—200 mesh, 75%—325 mesh and 30%—10 microns is used as the powdered fused silica. The material used is sold by Nalco Chemical Company under the trade name of "Nalcast P–1W," and is 99.8% pure, the principal impurity being alumina. This silica flour is mixed with 5 gallons of colloidal silica containing 30% by weight silica whose average particle size is 11–16 millimicrons. The colloidal silica weighs 10 pounds per gallon and is sold by Nalco Chemical Company under the trade name of "Nalcoag 1030." The resultant mix has a volume of 7½ gallons. In other words, the mixture includes 50 pounds of silica flour, 15 pounds of colloidal silica on a dry solids basis, and 35 pounds of water.

A quantity of ingot mold stools are cleaned by the use of a magnet to pick up loose material and the use of compressed air to blow off the remainder of the easily removable material on the upper surface of the stools. The coating material described above is then sprayed under pressure on the stools to a thickness of 1/8 inch. The stools are at a temperature of 400° F., and the coating quickly dries to a dense, hard, white coating.

Ingot molds are placed on the stools. Each ingot mold has a 38 inch by 56 inch average internal cross-section and is 96 inches high. The molds are placed on the stools big-end-down. Molten steel is then teemed into the molds and allowed to cool and the molds are stripped from the ingots. The ingots are then deposited in a soaking pit.

Among the ingots thus produced, there are no stool stickers at all, as compared to as much as 50% or so stool stickers experienced with previous methods. Upon repeated performance of the method with the same stools, negligible erosion is observed, the stools finally failing from thermal fatigue. Also, after slabbing and cropping and production of sheet and strip from the ingots pro-

duced according to the present invention, no inclusions of foreign material that could be attributed to the silica of the mold stool can be detected in the resultant sheets upon microanalysis using standard metallographic techniques. Upon continued use of the stools in this manner until failure, stool consumption in the course of the practice of the present invention proves to be less than half the stool consumption using practices previously known in this art.

Although the present invention has been described and illustrated in connection with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit of the invention, as those skilled in this art will readily understand. Such modifications and variations are considered to be within the purview and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A method of reducing the erosion of an ingot mold stool in the production of ingots from molten metal comprising applying a coating of a composition consisting essentially of a liquid dispersion of colloidal silica and pulverulent fused silica to the upper surface of an ingot mold stool, the colloidal silica being present in an amount effective to bind the fused silica into a hard coating, drying the applied coating to form a silica coating on the upper surface of the mold stool, and thereafter teeming molten metal into an ingot mold having the silica coated mold stool at the bottom thereof.

2. The method of claim **1** wherein the ingot mold has generally upright interior side wall surfaces that are substantially free of a silica coating.

3. The method of claim **1** wherein the ingot mold stool is at an elevated temperature when the coating of the liquid dispersion is applied.

4. A method of reducing the erosion of an ingot mold stool in the production of ingots from molten metal comprising applying a coating of a composition consisting essentially of a liquid dispersion of colloidal silica and pulverulent fused silica to the upper surface of an ingot mold stool, the liquid dispersion containing a ratio by weight of colloidal silica to pulverulent fused silica of about 1:5 to 1:1 on a dry solids basis, drying the applied coating to form a silica coating on the upper surface of the mold stool, and thereafter teeming molten metal into an ingot mold having the silica coated mold stool at the bottom thereof.

5. The method of claim **4** wherein the colloidal silica has an average particle size range of about 5–150 millimicrons and the pulverulent fused silica has a particle size range such that substantially all passes a 200 mesh screen.

6. A method of reducing the erosion of an ingot mold stool in the production of ingots from molten metal comprising applying a coating of a composition consisting essentially of an aqueous dispersion of colloidal silica and pulverulent fused silica to the upper surface of an ingot mold stool, the aqueous dispersion containing a ratio by weight of colloidal silica to pulverulent fused silica of about 1:4 to 1:2 on a dry solids basis, drying the applied coating to form a silica coating on the upper surface of the mold stool, and thereafter teeming molten metal into an ingot mold having the silica coated mold stool at the bottom thereof.

7. The method of claim **6** wherein the colloidal silica has an average particle size range of about 5–150 millimicrons and the pulverulent fused silica has a particle size range such that substantially all passes a 200 mesh screen.

8. A method of reducing the erosion of an ingot mold stool in the production of ingots from molten metal comprising applying a coating of a composition consisting essentially of an aqueous dispersion of colloidal silica and pulverulent fused silica to the upper surface of an ingot mold stool, the ratio by weight of colloidal silica to pulverulent fused silica being about 15:50 on a dry solids basis, the colloidal silica having an average particle size range of about 11–16 millimicrons, the pulverulent fused silica having a particle size range such that substantially all passes a 200 mesh screen, at least about 75% by weight passes a 325 mesh screen and at least about 30% by weight has a particle size less than 10 microns in diameter, drying the applied coating to form a silica coating on the upper surface of the mold stool, and thereafter teeming molten metal into an ingot mold having the silica coated mold stool at the bottom thereof.

9. A method of inhibiting erosion of the surface of the base member of a metal mold used to cast ingots, which erosion normally occurs during contact of said surface with flowing molten metal, while subsequently preventing adherence of said ingots to said base member upon ingot formation; which comprises the steps of applying to said surface a slurry comprising a refractory suspended in a binder, said slurry being applied in an amount sufficient to form a coating of sufficient thickness to inhibit said erosion and prevent said adherence and allowing said slurry to dry whereby a protective solid coating is formed upon said base member, said slurry comprising a vitreous silica refractory material suspended in a colloidal silica sol binder, with said binder being present in an amount sufficient to bind the refractory particles together to thereby form a tightly adherent coating which is bonded to said surface.

10. The method of claim **9** wherein said base member is cast iron, and said ingots cast are composed of steel.

11. The method of claim **9** wherein said slurry comprises 50–70 parts by weight of vitreous silica and 50–30 parts by weight of silica sol binder.

12. The method of claim **11** wherein said vitreous silica is fused silica which is characterized as having a silica content not less than 96% silica, expressed as SiO_2, and a thermal coefficient of expansion less than 5×10^{-6} cm./cm./° C.; and said binder is composed of about 30% by weight of substantially discrete, dense, non-agglomerated particles of silica colloidally dispersed in an aqueous liquid.

13. In a method of casting metal ingots from a metal mold whereby adherence of the base member of said mold to said formed ingots and erosion of said base member during formation of said ingots are substantially prevented; which comprises the steps of applying to the surface of said base member, a slurry comprising a vitreous silica refractory material suspended in a colloidal silica sol binder, said slurry being applied in an amount adequate to form a solid coating of sufficient thickness to inhibit said erosion and prevent said adherence, allowing said slurry to dry whereby the liquid phase of said slurry is driven from the surface of said base member leaving a thin film of refractory, pouring molten metal into said mold, allowing said metal to solidify into an ingot, and removing said ingot from said coated base member in said mold, said binder being present in an amount sufficient to bind the refractory particles together to thereby form a tightly adherent coating which is bonded to said surface.

14. The method of claim **13** wherein said coated base member is composed of cast iron and said ingots are steel.

15. The method of claim **13** wherein said slurry comprises 50–70 parts by weight of vitreous silica and 50–30 parts by weight of a silica sol containing about 30% by weight of silica colloidally dispersed in a hydrophilic continuous phase.

16. The method of claim **15** wherein said vitreous silica is fused silica which has a silica content not less than 96% silica, expressed as SiO_2, and a thermal coefficient of expansion less than 5×10^{-6} cm./cm./° C.; and said binder is composed of about 30% by weight of substantially discrete, dense, non-agglomerated particles of silica colloidally dispersed in an aqueous liquid.

17. An improved metal mold for casting metal ingots which comprises an open-top mold having at least its

base member coated with a thin solid protective film of refractory material derived from drying a slurry comprising a vitreous silica refractory material suspended in a colloidal silica sol binder, said binder being present in said slurry in an amount sufficient to bind the refractory materials together to thereby form a tightly adherent coating which is bonded to said base member, said coated base member being further characterized as being non-erosive to flowing molten metal and non-adherent to subsequently formed solid metal ingots.

18. The metal mold of claim **17** wherein said coating is derived from a slurry comprising 50–70 parts by weight of vitreous silica having a silica content not less than 96% silica, expressed as SiO_2, and a thermal coefficient expansion of less than 5×10^{-6} cm./cm./° C.; and 50–30 parts by weight of a colloidal silica sol binder.

19. The method of claim **9** where the pH of the colloidal silica sol is at least 11.0.

References Cited

UNITED STATES PATENTS

2,948,032	8/1960	Reuter	22—193
3,059,296	10/1962	North	22—193
3,184,813	5/1965	O'Shea	22—192
3,184,815	5/1965	Reuter	22—192

J. SPENCER OVERHOLSER, Primary Examiner

J. E. ROETHEL, Assistant Examiner

U.S. Cl. X.R.

117—5.3; 164—14, 138

Disclaimer

3,509,936.—*Joseph B. Kearfott*, Lincoln Park, and *Charles E. Baer, Jr.*, Birmingham, Mich. COATED ARTICLES AND METHOD OF REDUCING THE EROSION OF INGOT MOLD STOOLS. Patent dated May 5, 1970. Disclaimer filed Aug. 28, 1970, by the assignee, *Nalco Chemical Company*.

Hereby disclaims the terminal portion of the term of the patent subsequent to May 25, 1982.

[*Official Gazette December 8, 1970.*]