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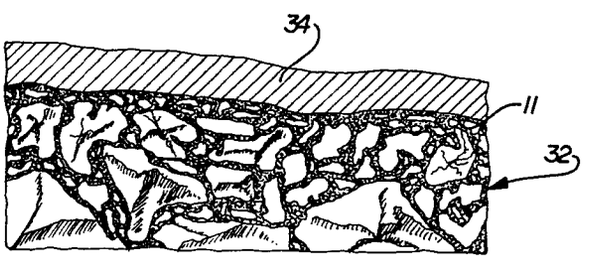
(54) Crucible liner and method of making and using the same.

(57) An improved crucible liner maintains a relatively thick reaction layer (34) on the inside of the crucible during pouring of a molten nickel chrome alloy. By maintaining a thick reaction layer inside the liner, the transfer of impurities from the crucible to a cast article is minimized. The liner is formed by impregnating the inside of the refractory liner (32) with an alkaline earth oxide such as calcium or magnesium. When a nickel chrome alloy is melted in the crucible liner, the alloy reacts with the liner and the alkaline earth oxide. The reaction products are deposited on the surface of the liner (11) and adhere to the surface of the liner during pouring.



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CRUCIBLE LINER AND METHOD OF MAKING AND USING THE SAME

Background of the Invention

The present invention relates to a new and improved crucible liner and a method by which the liner is made and used to promote the adherence of reaction products on the inner side surface of the liner during pouring of molten metal from the liner.

Nickel chrome super alloys are commonly used for the forming of vanes and blades used in gas turbine engines. When a nickel chrome alloy is melted in a crucible, the alloy reacts with the refractory materials of the crucible liner. This interaction results in the formation of reaction products or waste materials. When the molten metal is poured out of the crucible, these reaction products tend to flow along with the molten metal into the mold. The reaction products promote the formation of defects in a cast article.

Summary of the Invention

The present invention provides a new and improved crucible liner which promotes the tight adherence of a relatively thick reaction layer to the inside of the liner during pouring of a nickel chrome alloy. The liner is formed of a refractory material and is impregnated with an alkaline earth. The refractory liner may be impregnated with the alkaline earth by quickly pouring an aqueous solution of the alkaline earth into and out of the liner.

When a nickel chrome alloy is melted in the crucible liner, the alloy reacts with both the alkaline earth and the refractory material of the liner. An interaction occurs between the alloy, the alkaline earth and the refractory material to form a relatively thick layer of reaction product on the side surface of the liner. The layer of reaction product adheres tightly to the surface of the liner. This prevents the reaction product from entering a mold.

Accordingly, it is an object of this invention to provide a new and improved method of making a refractory liner for a crucible by impregnating the inside of the liner with an alkaline earth.

Another object of this invention is to provide a new and improved crucible liner which is formed by wetting the inside of a refractory liner with an alkaline earth solution.

Another object of this invention is to provide a new and improved method which includes providing an interaction between a molten nickel chrome alloy, an alkaline earth and a refractory material of a crucible liner to maintain a relatively thick layer of reaction product on an inside surface of the liner during pouring of the molten alloy.

Brief Description of the Drawings

The foregoing and other objects and features of the present invention will become more apparent upon a consideration of the following description taken in connection with the accompanying drawings wherein:

Fig. 1 is a sectional view of a refractory liner for a crucible;

Fig. 2 is a greatly enlarged fragmentary sectional view schematically illustrating the thickness of the reaction layer partially adhered to the inside of a refractory liner which was not impregnated with an alkaline earth; and

Fig. 3 is a greatly enlarged fragmentary sectional view schematically illustrating the thickness of the reaction layer which adhered to the inside of a refractory liner which was impregnated with an alkaline earth in accordance with the present invention.

Description of Specific Preferred Embodiments of the Invention

A new and improved liner 10 which is adapted to be placed inside a crucible in a manner similar to that disclosed in U.S. Patent No. 3,401,227. During use, a generally cylindrical cavity 12 inside the refractory liner 10 is partially filled with a nickel chrome alloy. The alloy is melted in a known manner by an induction coil. The molten nickel chrome alloy is then poured from the crucible into a mold to cast an article, such as a gas turbine component.

In accordance with a feature of the present invention, when a nickel chrome alloy is melted in the crucible liner 10, the alloy interacts with both the refractory materials of the liner and an alkaline earth with which the liner has been impregnated. The reaction products are deposited on the inside of the liner. During pouring of the molten nickel chrome alloy from the liner, the reaction products adhere to the inner side surface 11 of the liner and form a relatively thick reaction layer. This prevents the reaction products from entering a mold. By reducing the amount of impurities which enter the mold, the formation of defects in a cast article tends to be minimized.

The crucible liner 10 has a cylindrical refractory side wall 16 which extends upwardly from a circular bottom section 18 to an annular lip 20. If desired, the lip 20

could be shaped to promote the pouring of molten metal over a particular portion of the lip. Although the crucible liner 10 has a generally cylindrical configuration, it is contemplated that the crucible liner could have a different configuration if desired. The crucible liner 10 is formed of a refractory material such as fused silica, zircon and/or other materials in combination with suitable binders.

The crucible liner 10 is made by repetitively dipping a pattern into a slurry of ceramic mold material. Although many different types of slurry could be utilized, one illustrative slurry contained fused silica, zircon, and other refractory materials in combination with binders. Chemical binders such as ethyl silicate, sodium silicate and colloidal silica can be used if desired. In addition, the slurry may contain suitable film formers such as alginates to control viscosity and wetting agents to control flow characteristics and pattern wettability.

In accordance with a known practice, the crucible liner 10 was formed by first making a cylindrical aluminum plug which was covered with a wax coating to form a pattern. An initial slurry coating was applied to the pattern. The initial slurry coating contained a finely divided refractory material to produce an accurate surface finish. This initial slurry coating contained colloidal silica suspension, zircon and a relatively small amount of a wetting agent.

After the application of the initial coating, the surface was stuccoed with refractory materials. After stuccoing, the coating was dried and again dipped and stuccoed. The pattern was repetitively dipped and dried enough times to build up a covering of ceramic mold material of a desired thickness. The manner in which this was done is similar to that disclosed in U.S. Patent No. 3,401,227. After a covering of a desired thickness has been built up, the pattern is separated from the liner. The liner is then fired to about 1500-1800°F for one hour to remove residual pattern wax and strengthen the shell.

If desired, the residual pattern wax can be removed without firing the liner. This can be done by removing the residual pattern wax from the green or unfired mold with a known solvent such as trichloroethylene which is used to dissolve the residual pattern wax.

In accordance with a feature of the present invention, the liner 10 is impregnated with an alkaline earth. To this end, an aqueous solution of the alkaline earth is prepared. The alkaline earth solution is quickly poured into a liner 10. The solution is immediately poured out of the liner without allowing for any soaking time. If the residual pattern wax is removed by firing the liner, the liner will not be green when the alkaline earth solution is poured into and out of it. However, if a solvent is used to remove the residual pattern wax, the

liner will be green when the alkaline earth solution is poured into and out of the liner.

The wet refractory liner 10 is then at least partially dried. After a drying period, the alkaline earth treated liner 10 is fired. This may be either the first or second firing of the liner depending upon how the residual pattern wax is removed. The fired liner 10 is impregnated with the alkaline earth and is ready for use in a crucible. It is contemplated that the firing of the liner may take place as the crucible is heated immediately prior to melting the molten metal in the crucible.

In one specific instance, the liner 10 was treated with the alkaline earth calcium. Thus, an aqueous calcium nitrate solution was prepared. The calcium nitrate solution contained approximately 1.7 grams of hydrated calcium nitrate ($Ca(NO_3)_2 \cdot 4H_2O$) per cc of solvent. The solution was prepared by gradually adding 4,000cc of distilled water to 15 lbs. of hydrated calcium nitrate. The solution was stirred until the calcium salt completely dissolved in the water. If the solution is dirty, that is, if a suspension of dirt, foreign particles exist, the solution is filtered through a 65 mesh or finer sieve. The limiting factor on the reusability of the solution is its dirtiness. Therefore, after treatment of a plurality of liners, it is suggested that the solution be filtered.

The aqueous solution of calcium nitrate was quickly poured in a time period of approximately 5 to 7 seconds,

into a liner 10 which had been fired to remove residual pattern wax. The solution was then immediately poured out of the liner without allowing any soak time. The total lapsed time required to perform the steps of pouring the alkaline earth solution into and out of the liner 10 was less than two minutes.

In pouring the solution out of the liner 10, the solution was poured over the entire area of the lip 20 of the liner. This was done by twirling or rotating the liner 10 as the solution was poured out of the liner. By pouring the solution out over the entire lip 20 of the liner 10, whenever molten metal is poured out of the liner it will flow over a portion of the lip which has been impregnated with the alkaline earth.

Once the aqueous alkaline earth solution had been poured out of the liner 10, it was inverted and dried for a period of more than 15 minutes. A batch or group of treated liners 10 were then transferred to a preheat furnace which had been stabilized at a temperature of 1,500 to 1,800°F. The liners 10 were fired for a second time, at a temperature in excess of 1500°F for approximately one hour. This resulted in the formation of an oxide of the alkaline earth, that is calcium oxide, on the inside of each of the liners. After the liners had been removed from the furnace and cooled, they were ready for use in crucibles.

Although the foregoing description was in connection with the alkaline earth calcium, the alkaline earth magnesium has also been used. However, it is preferred to impregnate the refractory crucible liners with calcium oxide when a nickel chrome alloy containing hafnium is to be melted in the crucible. In the foregoing description, the refractory liner 10 was impregnated with calcium oxide by quickly pouring an aqueous solution of the alkaline earth into and out of the liner. However, it is contemplated that other methods of impregnating the liner 10 with the alkaline earth could be used if desired.

The treated and fired refractory liner 10 is placed in a crucible in a manner similar to that disclosed in U.S. Patent No. 3,401,227. The crucible liner 10 is then partially filled with a nickel chrome alloy. An induction coil surrounding the crucible liner 10 is energized to melt the nickel chrome alloy.

The molten alloy is exposed to both the refractory material which forms the base of the liner and the alkaline earth which has been deposited on the refractory material. Thus, the molten alloy can react with the refractory liner and the alkaline earth. The reaction products remain at the reaction site, that is at the surface 11 of the liner 10. When the molten metal is poured from the liner 10, the reaction products adhere tightly to the surface 11 of the liner with the resulting

formation of a relatively thick layer of reaction product on the inside of the liner. By maintaining a relatively thick adherent reaction layer inside the liner during pouring, impurities are prevented from entering the mold and causing defects in a resulting casting.

When a refractory liner 10 is not treated with an alkaline earth, a relatively thin, partially adherent and discontinuous layer of reaction product remains on the untreated liner after pouring of a nickel chrome alloy. The thin reaction layer remaining in an untreated crucible liner 10 after pouring of the nickel chrome alloy PWA 1422 (Mar-M200 plus hafnium) is schematically illustrated in Fig. 2. The surface 11 of the refractory base 24 of the untreated liner is substantially, but not entirely, covered with a relatively thin layer 26 of reaction product. In the one specific instance illustrated in Fig. 2, the this thin layer 26 of reaction product had a thickness of approximately 0.00005 inches.

Although the reaction layer 26 on the untreated refractory base 24 of the liner of Fig. 2 is relatively thin, it is partially adherent and the molten nickel chrome alloy within the liner reacted with the materials of the refractory base 24 of the liner to form a substantial volume of reaction products. The loose adherence of the layer 26 to the liner or refractory base 24 is shown by the spaces 28 between portions of the layer

26 and the base 24. Some of these reaction products, being partially adherent, were poured into the mold when the molten nickel chrome alloy was poured from the liner. Since the layer 26 of reaction product did not tightly adhere to the base 24, further reaction can take place between the molten metal and the base. In addition, portions of the loosely adhering layer 26 can wash away from the surface of the liner during pouring of the molten metal.

The relationship between a refractory base 32 of a liner 10 which has been treated with an alkaline earth and a relatively thick reaction layer 34 is shown schematically in Fig. 3. The molten nickel chrome alloy PWA 1422 in the liner 10 was exposed to both the refractory base material 32 of the liner and calcium deposited on the refractory base by using an aqueous solution in the manner previously explained. The molten nickel chrome alloy reacted with both the refractory base 32 and the alkaline earth to form reaction products which were deposited on the inner side surface of the liner 10. During pouring of the molten nickel chrome alloy from the liner 10, these products adhered tightly to the inner side surface 11 of the liner with a resulting thick layer 34 of reaction product.

In the specific instance illustrated in Fig. 3, the reaction layer 34 had a thickness of approximately 0.0005

inches. The reaction layer 34 which tightly adhered to the treated liner base 32 of Fig. 3 has a thickness which is ten times as great as the reaction layer 26 which is formed on the untreated liner base 24 of Fig. 2. By experimentation, it has been found that the reaction layer which remains in a refractory liner which has been impregnated with an alkaline earth is at least twice as great as the thickness of a reaction layer which remains in an untreated crucible liner. Of course, the specific thickness of the reaction layer which remains on the sidewall of a treated crucible liner after pouring of molten nickel chrome alloy from a crucible will vary depending upon the purity of the alloy and the composition of the alloy.

It is contemplated that the nickel chrome alloys which are melted in crucible liners impregnated with an alkaline earth in accordance with the present invention will be used to cast articles which are used under severe operating conditions, such as blades and vanes for gas turbine power plants in the manner disclosed in U.S. Patent No. 3,260,505. In one specific instance, a total of ten molds of twelve blades each were cast with a nickel chrome alloy. The blades were JT9D-7R second stage blades. All ten of the molds were cast of the same alloy. The alloy was PWA 1455 having a composition in accordance with United Technologies Corporation

specifications and corresponding generally to B1900 alloy with hafnium.

The molten nickel chrome alloy (specifically PWA 1455) for five of the ten molds was poured from refractory liners which had been impregnated with calcium in the manner previously described herein. The other five molds were filled with the same alloy poured from refractory liners which were of the same composition except that they were not impregnated with calcium. The results obtained from the pouring was as follows:

	Calcium Treated Liner	Untreated Standard Liner
Pieces inspected	60	60
Grain and green visual yield	97%	98%
First-time FPI yield	93%	88%
Overall FPI yield	98%	92%
Final X-Ray	93%	85%
Overall yield	88%	77%

Thus, there was an 11% higher overall yield from the molds which were filled with the molten nickel chrome alloy from liners 10 impregnated with calcium than from the molds which were filled with the same alloy from similar liners which were not treated with calcium.

In addition to the foregoing, JT9D-7A second stage vanes and JT9D-7R4 third stage vanes have been cast of the PWA 1455 nickel chrome alloy using liners impregnated with calcium. In each case, improved yield results were

obtained. When blades or vanes are to be cast of a nickel chrome alloy which does not contain hafnium, the refractory crucible liner may be impregnated with magnesium rather than calcium. In one specific instance, the nickel chrome alloy 713C was poured from a crucible liner impregnated with magnesium into a mold to cast a jet engine component. By experimentation, it has been established that the use of alkaline earth impregnated crucible liners 10 provides a greater improvement in yield of equiaxed castings than of columnar grained castings. However, it is believed that the use of alkaline earth impregnated liners will increase production yields of columnar grained castings.

In view of the foregoing, it is apparent that the present invention provides a new and improved crucible liner 10 which promotes the adherence of a relatively thick reaction layer 34 to the inside of the liner during pouring of a nickel chrome alloy, such as PWA 1455. The liner 10 is formed of a refractory material and is impregnated with an alkaline earth. The liner 10 may be impregnated with an alkaline earth, such as calcium oxide or magnesium oxide, by pouring an aqueous solution of the alkaline earth into and out of the liner before it is fired.

When a nickel chrome alloy is melted in the crucible 10, the alloy reacts with the alkaline earth and the

refractory material of the liner. During pouring of the molten alloy, an interaction between the alloy, the alkaline earth and the refractory material maintains a relatively thick reaction layer 34 on the inner side surface 11 of the liner 10. This prevents the reaction products from entering a mold and promoting the formation of defects in a cast article.

CLAIMS

1. A method of making a crucible liner which promotes adherence of a relatively thick layer of reaction product on the inside of a crucible during pouring of a molten nickel chrome alloy, said method comprising the steps of providing a refractory liner for a crucible, providing a solution containing an alkaline earth, and impregnating the inside of the refractory liner with the alkaline earth so that the alkaline earth and refractory liner can interact with the molten nickel chrome alloy to form a relatively thick layer of reaction product which can be maintained in the liner during pouring of the alloy.

2. A method as set forth in claim 1 wherein said step of impregnating the inside of the liner with the alkaline earth includes pouring the alkaline earth solution into the liner to wet the inside of the liner with the solution, pouring the alkaline earth solution out of the liner, and heating the liner after pouring the alkaline earth solution out of the liner to thereby deposit the alkaline earth on the inside of the liner.

3. A method as set forth in claim 2 wherein said step of pouring the alkaline earth solution into the liner

and pouring the alkaline earth solution out of the liner are performed within a time period of less than two minutes.

4. A method as set forth in claim 2 wherein said step of heating the liner includes heating the liner to a temperature in excess of 1500°F prior to being in contact with the molten metal.

5. A method as set forth in claim 2 wherein said step of providing a refractory liner includes the step of providing a liner having a lip portion over which the molten nickel chrome alloy is to be poured, said step of pouring the alkaline earth solution out of the liner includes the step of pouring the solution over the lip portion of the liner.

6. A method as set forth in claim 2 wherein said step of providing a refractory liner includes the step of providing a liner, said step of heating the liner includes the step of firing the liner.

7. A method as set forth in claim 1 wherein said step of providing a solution containing an alkaline earth includes the step of providing an aqueous solution containing calcium.

8. A method as set forth in claim 2 wherein said step of providing an alkaline earth solution includes the step of providing an aqueous solution containing magnesium.

9. A crucible liner formed by wetting the inside of a liner of a refractory material with an alkaline earth solution and subsequently firing the liner.

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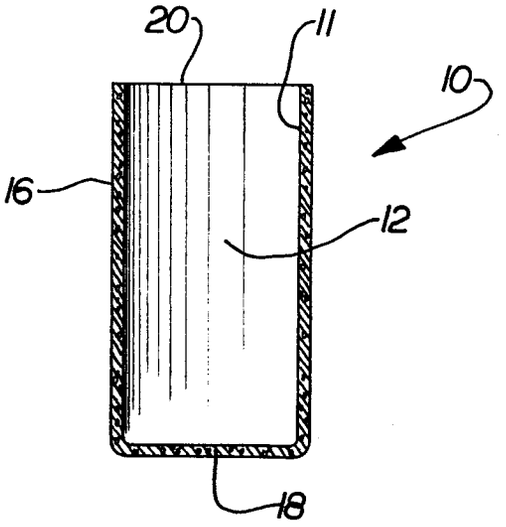

FIG.1

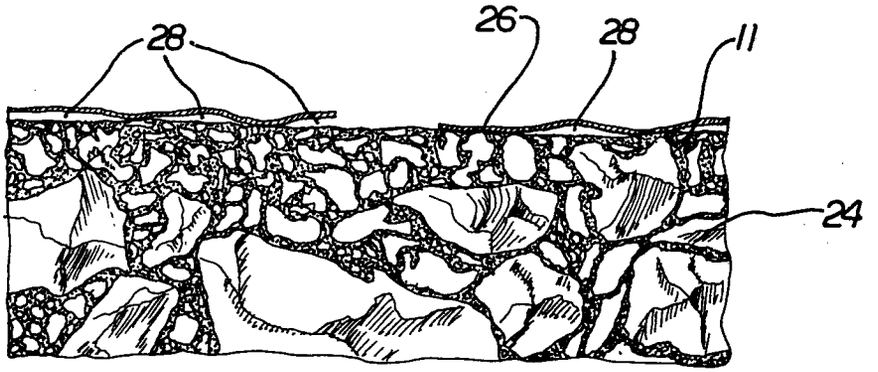

FIG.2

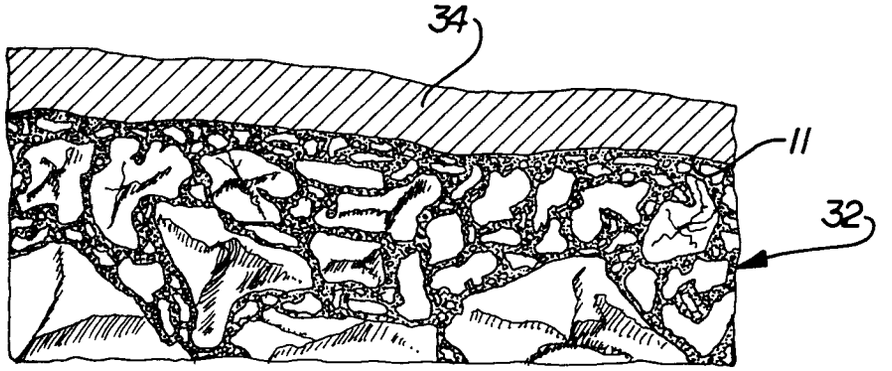

FIG.3

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EUROPEAN SEARCH REPORT

Application number
EP 83 30 2991

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	DE-B-2 038 442 (DEUTSCHE EDELSTAHLWERKE AG) * Claim 1 *	1	F 27 B 14/10 F 27 D 1/16 C 04 B 41/22
A	GB-A-2 019 988 (S.A. COCKERILL) * Abstract *	8	
D,A	US-A-3 401 227 (B.O. DUNLEVY et al.) * Claim 4; column 3, lines 7-10 *	1	
P,A	EP-A-0 065 034 (CHAMOTTE- UND TONWERK K. HAGENBURGER) * Claims 1, 3 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

F 27 B 14/00
F 27 D 1/00
C 04 B 41/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	22-08-1983	GOLDSCHMIDT G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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