POURING NOZZLE FOR CONTINUOUS CASTING LIQUID METAL OR ORDINARY STEEL

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8 Claims

ABSTRACT OF THE DISCLOSURE

In combination with a ladle having a bottom opening, a refractory nozzle having an induction coil surrounding it and a source of high frequency current for energizing the coil so as to inductively heat the interior surface of the coil to the temperature of molten metal being poured from the ladle.

In the casting of iron and steel by the continuous casting process, certain parts of the operations cause considerable difficulty. In order to maintain a uniform flow of metal to the mold, a steady ferrostatic pressure is highly desirable to insure the free movement of the cast steel away from the mold and produce a good surface with uniform dimensions.

Nozzles are a source of trouble. Their apertures are small, erode quickly during pouring or build up by silica, or nonmetallic alumina, adherence at the hole. This changes the size of the stream and, therefore, the rate of flow. This, in turn, affects the movement of the steel through the mold. Since the temperature of the liquid steel is usually high, it has an adverse effect on the ability of the nozzle to give good service.

An object of our invention is to provide a nozzle assembly which overcomes the above named disadvantages of conventional nozzles such as presently used in continuous casting systems or regular pouring of hot metals so as to assure constant and even flow of molten metal through the nozzle at all times and thus assure a perfect billet, ingot or slab.

A more specific object of our invention is to provide a novel nozzle assembly including an induction heated insert so constructed and arranged that the skin or hole-defining surface, through which the metal is poured, will be kept at sufficiently high temperature, that is, about or even higher than the temperature of the molten stream, so as to assure that metal or non-metallics will not solidify or freeze so as to constrict the size of the opening through the nozzle.

Other objects and advantages of the invention will become more apparent from a study of the following description taken in connection with the accompanying drawings wherein:

FIG. 1 is a schematic illustration of the top of the tundish and ladle assembly of a continuous casting system;

FIG. 2 is an enlarged, elevational view of the nozzle 22 shown in FIG. 3, two of which are shown at the bottom of the tundish 16 of FIG. 1;

FIG. 3 is a less enlarged, vertical cross-sectional view of a nozzle assembly including the insert 22 of FIG. 2 and an electrical, induction heating circuit for heating the nozzle 22;

FIG. 4 is a top view of the nozzle shown in FIG. 3; and,

FIG. 5 is a schematic diagram of a modification of the heating circuit embodying resistance heating.

The casting of hot metal through a nozzle into a mold, receptacle of some other container, presents some problems. If the stream of liquid metal going through the nozzle becomes lower in temperature and approaches or reaches its solidifying point, the nozzle aperture can partially or fully be clogged by such metal and stop the flow of metal. If such liquid metal contains material, foreign to its composition, this may solidify earlier than the parent metal, here again, some solidification may occur and thus block the nozzle aperture or reduce its flow. Our invention is effective to alleviate these conditions and allow the pouring of such liquid as desired.

Nozzles are usually made from a ceramic composition. They vary in design, hole size and composition. They may erode quickly due to the flow of the liquid metal which reduces their life.

This is true in some special steels which are not continuously cast, such as silicon, stainless, heat resisting or high aluminum steels and in continuous casting.

Referring particularly to continuous casting of steel, obtaining a good surface of the billet, bloom or slab is greatly dependent on maintaining an even, constant ferrostatic pressure on the mold. When the pressure varies, it affects the complete filling of the mold and results in cross sections that are of unequal dimensions. It may even result in a center which may be porous or a large secondary pipe may be formed. Thus can be seen the necessity of maintaining an even pouring rate and to keep the nozzle properly functioning at all times. A further risk occurs when there are more than one strand operating, if one or more nozzles become out of order it puts an extra burden on the remaining strands and the temperature of the metal in the tundish may not be high enough to maintain the fluidity of the remaining metal to complete its full pouring.

Again, when the pouring temperature of steels falls below approximately 2900 degrees F., a film of non-metallics with or without iron begins to form in the nozzle and gradually builds up until the nozzle may be completely or nearly completely closed, thus shutting down that part of the equipment.

This non-metallic buildup causes a restriction on the amount of aluminum that can be used, usually .4 lb., maximum of aluminum per ton. This restricts the use of continuous casting to certain grades of steel. Steels such as deep drawing sheet steels which are made in large tonnages in the regular manner and must use in excess of 2 pounds of aluminum per ton of steel may not be made by the continuous process using the old type nozzles.

Our heated nozzles overcome most of the clogged nozzle troubles.

We propose to have built into the nozzle, an insert which will carry an electrical current. This insert will be part of the nozzle and the part of the insert that is exposed to the flow of metal may be coated or plated with a high temperature heat resisting material or ceramic to prevent wear or rapid erosion. The temperature of the area in the nozzle, where clogging usually occurs, will be maintained above the melting point of the clogging material thus keeping the nozzle clear for uninterrupted pouring.

Referring more particularly to FIG. 1, numeral 10 generally denotes the initial section of a casting system, embodying a ladle 12 having a stopper 13 which opens and closes a hole 14 at the bottom thereof to allow molten metal to pour into a tundish 16. The tundish has holes (two being shown) at the bottom thereof fitted with refractory nozzles through which molten metal is poured into two oscillating, water-cooled molds to form a pair of strands of cast steel 20, 22. These strands, in a known manner, are then conducted to pinch rolls, billet bending rolls, discharge chutes for charging the direction of the strand from vertical to horizontal, a billet straightener, and an automatic cutting machine for cutting the billets into lengths which are then stacked.

Referring more particularly to FIGS. 2, 3 and 4, numeral 22 generally denoted a nozzle insert which is
closely fitted into a ceramic nozzle 34 of zirconium oxide or other suitable substantially nonelectrically conductive refractory material. The insert comprises a conductive material, such as portion 28 of graphite, which forms a close and tight fit inside the correspondingly shaped, well portion formed in nozzle 34. The insert 22, or at least the refractory plug 38 may be replaced from time to time without the necessity of replacing the induction coil 42.

In the molten stream a surface coating 32 of about .02 to about .03 inch thick is provided on the surface of portion 28 which defines the aperture 30 which is in registry with aperture 40 of plug or nozzle 34. This hard surface coating 32 may be of silicon carbide, tungsten carbide, zirconium oxide, zirconium carbide, boron carbide, yttrium boride or oxide or similar materials that will resist erosion by a molten stream of about 2,950 degrees F. It was found that the abovementioned difficulties of clogging could be averted by raising the temperature of the bore surface of the nozzle by about 100°F above the casting temperature or the melting point of the clogging material.

In order to heat the carbon insert portion 28 and coating 32 to at least a temperature of about 2900° F. or perhaps higher than the molten stream temperature of about 2900°, we have found the most efficient mode is induction heating, which is done by a helical induction coil 42 closely surrounding the ceramic nozzle or plug 34, which coil 42 is energized by a motor generator 60 through a pair of line conductors 44, 46, across which are connected a fixed condenser 48 and a plurality of variable condensers 50, 52, 54, 56, and 58 which are inserted in the circuit as the temperature increases since electrical properties change with the temperature. Such condensers are used to compensate for variations occurring before and during operation of the continuous casting system or regular liquid metal pouring.

A unique feature of the invention is that the induction heating will not appreciably raise the temperature of the ceramic nozzle 38, but will considerably increase the temperature of the graphite liner or insert 22, particularly the coated surface 32, where the high temperature is mostly needed so as to prevent corroding or solidification of metal from the molten stream passing through apertures 30 and 40. The principles of induction heating as contrasted with other means of heating are summarized in Chemical Engineers Handbook, 4th edition, pp. 2541 to 2543, by John H. Perry, McGraw-Hill Book Company. The coated surface 32 may be kept perhaps 50°F below, or higher, or at the same temperature as that of the molten stream.

If another suitable coating bonding for the graphite insert with sufficiently long life is desired, the insert itself may be of other materials than graphite, such as zirconium carbide ZrC or zirconium diboride ZrB2 or Yttria zirconia.

It should be especially noted that for the highest efficiency, induction heating frequencies may range from about 7 to 30 kilocycles. For small hole diameters of about 1/2 inch, 3 to 7 kilocycles may be suitable, but for holes of the order of 1¼ inch and up, the frequency may be in the range of 40 to 50 kc. For extremely high frequencies, such as 15 to 50 kc, a mercury gap oscillator may be employed.

In operation, the tundish 16 is preheated in the regular manner and the metal is allowed to flow in from the ladle 12. The current is turned on in advance to the nozzle 18 or the surface exposed to the liquid steel and its temperature raised to 2900 degrees F. or higher, as desired. This temperature is maintained throughout the pour.

The present induction heating system may also be modified so that the molten stream involves substantially greater power consumption than the use of induction heating, which induction heating provides eddy currents for heating the surface of the carbon portion 28 and coating 32.

FIG. 5 shows a modification involving a source of A.C., 80 for energizing the primary of a transformer 68 after closing of switch 82 of the primary circuit, whereby the secondary coil passes current through a fixed resistor 64 and a variable resistor 66, which resistors may be embodied in an insulating insert substituting for the insert 22 of FIG. 3. However, resistance heating, as shown in FIG. 5, is not very efficient as compared to the induction heating system shown in FIG. 3.

A further modification could be capacitance or dielectric heating, involving embedding a proper electrodes in an insulating insert, shaped like Insert 22, and applying a source of potential across such electrodes. However, such capacitance heating is likewise not as efficient as the induction heating system shown in FIG. 3.

While the novel nozzle assembly embodying the present invention has been described in connection with a continuous casting system for improving the flow of molten metal, it has also other general applications, such as in the ladle 12 or in any other ladles or containers wherein it is desired to make sure that solidification will not clog the outlet hole thereof when a liquid metal is to be poured through a relatively large opening.

While induction coil 42 is shown as surrounding the ceramic nozzle 38, it could be positioned in an annular well portion formed therein, instead, for additional protection.

Thus it will be seen that we have provided an efficient nozzle assembly embodying a ceramic nozzle having an electrically conductive insert which is inductively heated at the surface thereof to very high temperatures, approximating or exceeding the temperature of the molten steel poured therefrom so as to prevent solidification or congealing of metal and clogging the hole opening.

While we have illustrated and described several embodiments of our invention, it will be understood that these are by way of illustration only, and that various changes and modifications may be made within the contemplation of our invention and within the scope of the following claims.

We claim:

1. In combination with a container having at the bottom thereof a nozzle composed of a substantially nonelectrically conductive refractory material through which molten metal is poured, an induction coil surrounding the nozzle opening, and an electrically conductive insert disposed in the nozzle opening, an electrically conductive insert surrounding the nozzle opening and fitting into a well portion formed in the opening of said nozzle, and a source of high frequency current in the range of between about 3 to 50 kc. for energizing said coil so as to inductively heat the insert in said nozzle to substantially the temperature of said poured molten metal.

2. The combination recited in claim 1 wherein said refractory nozzle is formed from a material selected from the group consisting of zirconium oxide, zirconium carbide and zirconium diboride.

3. The combination recited in claim 1 wherein a graphite insert surrounds the nozzle opening.

4. The combination recited in claim 3 wherein a coating of a material selected from the group consisting of zirconium oxide, zirconium carbide, boron carbide and yttrium carbide or oxide is provided on the hole-defining portion of the nozzle to protect the graphite from erosion.

5. The combination recited in claim 4 wherein said graphite insert is provided with a refractory protective coating to prevent erosion by the molten metal.

6. The combination recited in claim 5 wherein fixed and variable condensers are connected in parallel with said induction coil.

7. A method for preventing the congelation of molten metal in passing from a receptacle through a substantially
nonelectrically conductive nozzle orifice to maintain uniform flow thereof, comprising lining the orifice with an electrically conductive insert, applying a protective refractory coating to the insert, disposing an induction coil about said nozzle, energizing the coil with a high frequency current to inducively heat the insert to substantially the temperature of the molten metal.

8. That method of assuring maintenance of constant ferrostatic pressure on a mold in the continuous casting of steel by preventing solidification of metal in a substantially nonelectrically conductive nozzle used in said continuous casting comprising, installing in said nozzle a refractory electrically conductive insert having a substantially centrally located passageway, there being an induction coil about said nozzle, energizing said coil with a high frequency current sufficient to maintain the insert defining said passage at substantially the temperature of the steel to thereby prevent the formation of a film and the gradual building up thereof in said passage which would close said passage thereby assuring a constant ferrostatic pressure while said molten metal is flowing through said passage.