DIP FORMING METHOD
Roland P. Carreker, Jr., Schenectady, N.Y., assignor to General Electric Company, a corporation of New York
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3 Claims

ABSTRACT OF THE DISCLOSURE

In a dip crucible apparatus for accreting molten metal onto a moving core rod passing through a crucible containing molten metal, an annular baffle is disposed concentrically to the crucible wall defining a reservoir of molten metal and surrounds the core rod. The baffle has a plurality of openings, one at its lower end, and a feed inlet to the crucible is positioned below the upper edge of the baffle but above the openings in the baffle. Molten metal introduced to the crucible flows downwardly between the crucible walls and the baffle and countercurrently within the baffle.

My invention relates to an improvement in dip casting and particularly to a method and apparatus for eliminating the periodic formation of massive deposits of metal on a rod moving through a casting crucible.

The process of dip casting is described in many of its aspects in U.S. Patents Nos. 3,008,201; 3,060,053; 3,060,054; 3,060,055; 3,060,056; 3,094,752; and 3,235,960. Other aspects are described in more recently filed U.S. application Ser. No. 538,370, filed Mar. 29, 1966, now abandoned in favor of continuation-in-part application Ser. No. 633,325, filed Mar. 8, 1967, and assigned to the same assignee as this application.

The present invention relates to another of the several aspects on which the successful operation of the invention of a commercial scale may be seen to depend. Commercial operation requires, of course, that a core rod be processed continuously through a casting crucible and that the product formed have sufficient uniformity of properties and dimensions that it may be fed on a continuous basis through a variety of possible succeeding processing operations or stations depending on the nature of the product being formed and the conditioning of forming which may be needed to render it suitable for future use. From the above patents it will be appreciated that the product leaves the crucible at a speed of about 200 linear feet per minute and that higher speeds are, of course, possible and contemplated.

A great deal more importance therefore attaches in the commercial use of the dip forming technology to the requirement for preventing the developments of product irregularities or the like, than attention to ways of overcoming, correcting or compensating for such irregularities after they have occurred.

A serious source of product irregularities in production operation of the dip forming process is the periodic formation of bumps or bump like irregularities on the rod. The bumps are adherent deposits of solid metal which may be the general form or shape of an asymmetrical protuberance and in the more pronounced cases tend to have radial symmetry and cover the entire 360° of the rod site where the deposit occurs. In such cases the deposit flares gradually outwardly in the downstream direction from the normal rod diameter to a maximum diameter and then curves sharply under to a relatively flat bottom where the rod is against its normal diameter. In general appearance the shape is that of a bell. The bells are deposited generally symmetrically to the ascending rods so that the rod forms a vertical axis extending through the center of the bell.

This product defect has been found to occur in many applications of the dip forming process, particularly it has been found to occur on castings emerging from casting crucibles of various designs, at different rates of casting, at different casting temperatures and differential casting temperatures (differential temperature between core and melt in the casting crucible) and when casting different combinations of metals, including the casting of copper on copper, copper on steel, and steel on steel, among others.

These defects in the product rod vary in size from the barely perceptible to more than double the normal diameter of the emerging rod. The defects occur intermittently, depending apparently on prevailing conditions, at intervals of one to many feet and sometimes almost periodically depending on other conditions.

As to the damage caused by these irregular accretions, to take the specific case of dip forming copper wire rod, small partial bells were found to occur under a specific set of operating conditions at a spacing of about one at every six feet of product rod. Before these irregular accretions were understood to be the source of damage, a series of major transverse cracks were discovered at these sites following the hot rolling of the product rod, the hot rolling having been effective to obscure the bells from the rolled rod product.

One object of the present invention is to provide a method which substantially eliminates the deposit of excessive accretions on a dip formed rod.

Another object is to provide an apparatus which is effective in minimizing the occurrence of irregular accretions on dip formed rod products.

Other objects will be in part apparent and in part pointed out in the description which follows.

In one of its broader aspects the objects of the present invention may be carried out by channeling the flow of liquid metal in the casting crucible to minimize the tendency of liquid metal proximate the entry port to freeze.

In another of its aspects the objects may be achieved by providing an annular flow baffle in the casting crucible, said baffle cooperating with the inner crucible walls and providing an axially inward flow of metal in contact with the lower wall of said crucible toward the entrance to said crucible.

The invention will be understood with greater clarity in reading the description which follows by reference to the accompanying drawings in which:

FIGURE 1 is an axial vertical section of a casting crucible as used in dip casting of metals.

FIGURE 2 is an elevation of a rod on which an oversize bell has deposited in a casting crucible such as illustrated in FIGURE 1.

FIGURE 3 is an axial vertical section taken along the line 3—3 of FIGURE 4 and similar to that shown in FIGURE 1 but differing in that it illustrates the incorporation of the flow baffle of the present invention.

FIGURE 4 is a horizontal section taken along the line 4—4 of FIGURE 3 and illustrating the positioning of the use of the flow baffle of the present invention.

Referring first to FIGURE 1, the rod 10 on which metal is to be accreted is surface cleaned and fed to the crucible entrance 14 by means not shown but now known in the art as pointed out above. The rod 10 enters the bottom entrance 14 of a dip casting crucible 12 under vacuum produced also by means not shown but now well known in the art as pointed out above.

The rod 10 enters the crucible 12 through entrance port 14 in the nozzle 16. The dimensions of the nozzle 16 in relation to the entering rod and the temperature at which the nozzle is maintained is critical for successful
efficient operation of the process. The basis for this criticality is essentially as follows.

Within the crucible a bath of molten metal is maintained at a depth sufficient to permit a metal rod entering from port 14 to remain in contact with the metal for a time designated conveniently as a residence time. The residence time obviously depends on the depth of the bath 18 and on the linear rate of movement of the rod 10. Increasing rates of rod movement require greater depths of molten metal to provide the same residence time of a unit segment of the rod in the bath.

Increasing bath depths are therefore advantageous where higher linear rates of dip forming are to be carried out. However, the increased bath depth results in an increased pressure of liquid at the lower end of the crucible and the increased linear rate of movement of the rod takes heat away from the bottom entry crucible nozzle 16 at a greater rate than occurs at the slower casting rates.

Under the high pressure of liquid metal a flow of this liquid metal tends to occur through any opening and in the apparatus of FIGURE 1 it tends to occur between the outer surface of the nozzle 16 and the inner surface of the graphite container 20 which makes up the body of the crucible.

The way in which a leakage at this point can be avoided, and a metal nozzle insert provided without such leakage at this point, is by maintaining a temperature differential lengthwise of the nozzle so that the melting point of liquid and the outer end is below the melting point of the liquid metal. With this temperature differential the outflow of liquid metal is prevented by the solidification of the metal which flows into the potential flow paths between the graphite crucible and the molybdenum insert.

The use of the nozzle insert is essential to provide a surface which will not be worn or abraded as the surface of graphite would be by the rapidly moving metal core rod entering the liquid metal bath. A molybdenum nozzle insert has been found satisfactory for this purpose and is effective in permitting high velocity entry of copper rod to the copper melt in the crucible on a continuous basis.

However, it will be appreciated that where the rapid passage of lower temperature core rod into contact with and through the nozzle insert lowers the temperature of the liquid metal at the lower end of the crucible, it is not sufficient to add heat to this portion of the crucible to overcome this cooling. The reason is that any addition of heat as from the heating elements such as 22 must depend in part on elimination of the thermal gradient which has been found to provide the effective seal between the insert 16 and graphite of crucible 20.

To add heat to the lower end of the crucible by heating the liquid metal in the crucible to a higher temperature also has the adverse effect of lowering the efficiency of the casting. Lowered efficiency results when casting a melt appreciably above the melting temperature because part of the heat capacity of the rod is used up in lowering the temperature of the metal to be accreted to the casting temperature before the metal can be solidified through absorption into the core rod of the additional heat representing the latent heat of fusion of the accreted metal.

Accordingly, while deep baths are desirable for high casting rates, the operation of these baths at the high temperature is undesirable because of lowered efficiency of operation. Also, addition of heat at the crucible bottom can disrupt the fluid seal maintained mainly through maintenance of the temperature gradient from the molten metal of the crucible to the frozen metal seal around the nozzle insert.

The present inventor has recognized that the origin of the bumps, bells and other surface irregularities on the rod product of the dip casting process may be the result of the need for maintaining the close balance of temperature in a crucible in which a very rapid heat exchange process is taking place. The high rate of heat exchange is evident from the fact that metal is cast at a rate of more than two hundred pounds per minute from a crucible having a melt depth of about fifteen inches and a diameter of 6 inches.

Stirring of the metal melt to develop a more uniform melt temperature in the casting crucible is useful in reducing bump formation but is mechanically cumbersome and becomes increasingly so as the depth of the crucibles are increased.

Use of increased insulation at the crucible bottom is also useful but does not reduce the large central heat leak which results from the movement of the core rod through any insulation wall and into the melt.

Increasing rod temperature also has the effect of reducing the overall efficiency of the casting in reducing the amount of metal which can accrete on a rod of given composition and dimensions.

Returning now to the description of FIGURE 1, the supply of liquid metal is through a graphite tube from a source not shown. Heat may be supplied by means of an induction heating coil 22. The crucible is also provided with a lid 26 to assist in temperature and atmosphere control. The rod 10, enlarged by the accretion of metal, emerges through the exit port 24.

Referring next to FIGURE 2, an elevational view is provided illustrating the form of a severe bell.

Turning now to the apparatus by which the problems of bump and bell formation as described above are overcome within the efficiency of the apparatus, this apparatus is illustrated in vertical section in FIGURE 3 taken along the line 3—3 of FIGURE 4, and in horizontal section in FIGURE 4 as a view taken along the line 4—4 of FIGURE 3.

The elements described with reference to FIGURE 1 above are duplicated in FIGURE 3, the like reference numerals indicating like parts but the numerals being distinguished in FIGURE 3 by the addition of a prime.

In the improved apparatus of this invention there is in addition to the portions described with reference to FIGURE 1 two additional elements adapted to provide the advantages of the present invention.

The first is the annular baffle element 30 and the second is the baffle spacer 32.

The annular baffle is shown disposed generally concentrically to the crucible walls and to the rod 30 passing through the melt. It will be evident from the description which follows of the construction, while important in certain applications, may be modified in others, particularly for example with reference to casting onto rods of different cross section or on to sheet or other stock of irregular cross section.

The baffle 30 has radially extending slots 34 at its lower ends which, when the baffle is in place in the crucible with its slotted end against the lower internal surface of the crucible, form radially extending channels for flow of the liquid metal from the outer annular reservoir 36 to the inner annular reservoir 38.

A number of advantages occur through use of this arrangement as follows.

First, the arrangement of the crucible melt into two generally concentric annular flow paths provides a generally countercurrent flow of liquid metal.

Accordingly, this arrangement, rather than reducing or eliminating the temperature gradients in the casting crucible, can have the effect of increasing such gradients. This capability of the apparatus of the present invention to increase the efficiency of operation of the casting process is dependent on the discovery that while the generation of temperature gradients can have a deleterious effect on processing efficiency as explained above, it is possible to arrange the liquid metal flow that the existence of temperature gradients can actually add efficiency to the processing.

To illustrate this, and with reference for this illustration to FIGURES 3 and 4, it is evident that a heat source such as induction heating coil 22 will provide a delivery
of heat at the inner surface of the outer crucible wall. Accordingly, liquid metal of lower temperature entering the crucible 12' from supply tube 24' will accept heat from the crucible wall inasmuch as the flow of metal is confined by the baffle 30 to an outer annular flow path in the crucible. Accordingly, the metal must leave the outer annular flow path at a minimum temperature controlled in part by its temperature on entering the outer annular flow path and in part on the temperature of the outer crucible wall which partially defines the outer annular path.

It is by this ensuring that the metal which leaves the annular flow path will have a desirable minimum temperature that the prevention of accretion of material proximate the bottom entry port is accomplished in accordance with this invention. What is significant about this aspect of the innovation in increasing the efficiency of operation of the dip casting process is not simply the raising of the temperature of the melt in this area of the crucible, but rather in increasing the reliability of maintenance of the temperature of this portion of the melt at the optimum temperature for high efficiency operation. What is also significant is the avoidance of the raising of the average temperature of the entire melt to do so and avoiding raising the temperature of the frozen seal where it is used between the crucible bottom and the metal insert 16 which receives the core rod.

A temperature gradient which extends along the inner of the two interconnected annular columns of liquid metal can be advantageous in bringing the temperature of this column closer to the casting temperature without risk of the formation of surface irregularities such as the bumps and bells described above.

A significant secondary advantage of establishing and maintaining throughout operation the two interconnected annular columns of liquid metal by means such as baffle 30 is that metal bath 18' is continuously skimmed. Thus, foreign matter such as pieces of refractory and slag entrained in the liquid metal entering crucible 12' through supply tube 24', being lighter than the liquid metal, is blocked from access to the liquid metal column within baffle 30 and collects in the upper portion of the column of liquid metal surrounding baffle 30.

What is claimed is:

1. In a method of accreting metal onto a core rod comprising passing said rod through a molten bath of metal contained in a crucible to accrete metal thereon and removing the resulting cast rod from said crucible, the improvement comprising: (a) establishing in said crucible an interior melt zone through which said rod passes and a substantially concentrically disposed exterior melt zone provided by an annular baffle having a plurality of openings at its lower end for establishing communication between said zones, (b) continuously introducing molten metal to the upper part of said exterior zone to substantially fill both of said zones of said crucible, (c) establishing a downward flow of molten metal in said exterior melt zone and a countercurrent upward flow of molten metal in said interior melt zone, (d) supplying heat to the outer surface of said exterior zone to maintain the temperature thereof above a minimum and withdrawing heat from the interior zone, and (e) inducing flow of molten metal between said zones at least partially by the removal of substantially solid metal from said interior zone.

2. In a method according to claim 1 wherein said core rod and said molten metal are both copper.

3. In a method according to claim 1 wherein said core rod and said molten metal are dissimilar metals.

References Cited

UNITED STATES PATENTS

1,426,683 8/1922 Stilhane et al. --- 164—86 X
1,589,329 6/1926 Sheppard et al. ------- 117—115
2,072,060 2/1937 Schultz --------------- 164—64 X
2,123,894 7/1938 Hazelett --------------- 29—33
2,127,413 8/1938 Legulion ------------- 117—115 X
2,231,142 2/1941 Schultz --------------- 164—275
2,543,936 5/1951 Reynolds ------------- 22—572
2,702,523 2/1955 Whithfield.

J. SPENCER OVERHOLSER, Primary Examiner
V. RISING, Assistant Examiner

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