METHOD OF AND APPARATUS FOR CONTINUOUSLY CASTING A HOLLOW BILLET

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ABSTRACT
Melted metal, typically copper, is applied through floating valve means to a water-cooled mold containing a mandrel of special form and materials so as to result in continuous downward movement of the solidified billet through the bottom lower end of the mold and over the lower end of the mandrel.

30 Claims, 3 Drawing Figures
METHOD OF AND APPARATUS FOR CONTINUOUSLY CASTING A HOLLOW BILLET

BRIEF SUMMARY OF THE INVENTION

The present invention relates to continuous casting, and more particularly, to continuous casting of a hollow copper billet dimensioned for use in tube extrusion apparatus.

There is provided a relatively short cylindrical water-cooled mold of substantial diameter as for example having an inside diameter in excess of 9 inches. Suspended from the top of the mold is a mandrel comprising a rod of heat resistant alloy, an upper sleeve of a refractory material such as for example silica, and a lower sleeve of graphite. The lower graphite sleeve of the mandrel has an upper cylindrical portion, and a lower slightly tapered portion which prevents seizing as the solidification of the descending billet causes contraction thereof.

Molten copper is introduced into the annular space between the water-cooled mold and the mandrel from a downspout which is controlled by a vertically movable float valve the lower portion of which is received in the upper portion of the molten metal in the mold. As the level of the metal in the mold moves downwardly in the continuous casting process, the float valve continuously meters the flow of molten metal into the mold to maintain the upper level of the surface of the molten metal at a substantially constant point.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of the continuous casting apparatus.

FIG. 2 is a side elevation, partly in section, of the structure shown in FIG. 1.

FIG. 3 is a sectional view on the line 3—3, FIG. 1.

DETAILED DESCRIPTION

The apparatus comprises a water-cooled cylindrical mold 10 having in a particular instance, an internal diameter of approximately 9 inches and a vertical height of somewhat in excess of 12 inches. This mold is suitably water-cooled by means, as for example, in the form of a water jacket 11 through which cooled water may be continuously circulated. The mold is supported with its axis vertical as best seen in FIG. 3, by suitable means such as for example as the ring 12. Mounted on the ring 12 is a bridge ring 14 comprising two arcuate portions 16 interconnected by a transverse strut 18 which is horizontal across the top but has tapering bottom surfaces to provide increased central thickness as best seen in FIG. 2. The strut 18 is centrally apertured as indicated at 20 and receives an elongated headed bolt 22 formed of a suitable heat resistant metal alloy such as for example TZM molybdenum alloy, a molybdenum base alloy supplied by Climax Molybdenum Company. Other metals can be used however, and satisfactory results have been obtained using a nickel base super-alloy Inconel 718.

Mounted on the upper portion of the bolt 22 is a sleeve 24 formed of a suitable refractory material capable of operating in the severe chemical environment characteristic of the molten metal surface of the copper. Usually, there is a molten oxide slag floating on the upper surface of the molten copper including complex copper phosphorous oxide. Such a molten oxide severely attacks solid metal and graphite. Accordingly, the sleeve 24 is formed of a high temperature resistant material capable of resisting attack by the slag. An excellent material for this purpose is essentially a fused silica.

Referring to FIG. 3 it will be observed that the upper level of the molten copper is maintained by suitable means later to be described, approximately as indicated at L, and this upper surface of the molten metal where the slag is present, falls intermediate the upper and lower ends of the fused silica or other heat resistant and chemically inert sleeve 24.

The mandrel which is designated as a whole at M, has at its lower portion a sleeve 26 formed of graphite. The sleeves 24 and 26 are retained in end-abutment and the upper end of the sleeve 24 is in abutment with the lower surface of the transverse strut 18 of the bridge ring 14 by a washer 28 and nuts 30 threaded on the lower end of the bolt 22.

The refractory sleeve 24 is of external cylindrical configuration and in a typical example has a diameter of approximately 2 inches. The upper end of the graphite sleeve 26, as indicated at 32, has an external cylindrical sleeve equal in diameter to that of the refractory sleeve 24. The lower portion of the graphite sleeve, as indicated at 34, is slightly downwardly tapered and is connected to the cylindrical upper portion 32 by a small shoulder 36. In a typical embodiment of the invention the upper cylindrical portion 32 and the lower tapered portion 34 of the graphite sleeve are both 6 inches in length. The lower tapered portion diminishes from an outside diameter at the shoulder 36 from 1.86 inches to a diameter at its bottom end of 1.80 inches.

The purpose of the taper is to accommodate shrinkage of the copper billet as it solidifies and moves downwardly so as to prevent seizure of the contracting billet on the mandrel. Above the shoulder 36 the molten copper, while cooling, retains essentially a fluid character so that no taper is required on the upper portion 32 of the mandrel.

The molten metal is supplied to the interior of the mold 10 from a pan 40 having a tubular downspout 42 located centrally of and above the upper surface of the mold 10. In order to control the flow of molten metal through the downspout 42 so as to maintain the level L of the molten metal substantially as indicated at L, as the metal continuously solidifies and moves downwardly, there is a vertically movable float or valve body 44. The float 44 is formed of a relatively light refractory material which can withstand the high temperature as well as the chemical action of the molten copper, as well as the slag floating at its surface, and in addition is of a relatively light material so that it floats on the top of the molten copper.

The float is made from a castable refractory and chemically inert powder which may be essentially powdered silica. The powder is mixed with water, cast to desired form, and fired in a furnace. The density of the material is less than 20 percent that of copper so that the float will extend substantially above the surface of the molten metal as shown.

The float 44 has a generally cylindrical exterior surface 46, a flat bottom surface 48, and a transversely downwardly open channel 49 having side surfaces 50 and a top surface 52. The channel 49 provides a structure which permits the float to straddle the transversely extending strut 18 of the bridge ring 14.
Extending across the top of the float 44 is a transverse channel 54 the intermediate portion of which is deepened as indicated at 56 to have a bottom wall 58. Centrally of the bottom wall 58 is an upstanding cone 60 adapted to function as a valve element with the lower end of the downspout 42. The deepened intermediate portion 56 of the transverse channel 54 constitutes a reservoir which receives molten metal from the downspout 42 and this metal flows through vertical passages 62 connected by inclined passage 64 to the interior of the channel 49. It will be observed that with the parts in the position illustrated in FIG. 3, the outlet from the inclined passages 64 is substantially centered at the liquid level line L and thevalving cone 60 is in closing relation to the downspout 42.

The float 44 floats on the upper surface of the molten metal and constitutes valving means which maintains the level as indicated in FIG. 3. As the metal in the mold 10 solidifies due partly to the cooling of the mandrel by the water-cooled mold 10, the molten metal solidifies gradually at a zone approximately at the shoulder 36 on the mandrel. As the substantially solidified metal of the billet continues to move downwardly and cools further, it undergoes shrinkage which is accommodated by the tapered shape of the lower portion 34 of the graphite sleeve. In addition, the graphite sleeve, while being capable of functioning at the elevated temperatures of the molten copper, also has the additional function of promoting downward movement of the solidifying billet due to its inherent characteristic of a solid lubricant.

In operation, molten metal may be added continuously through the downspout 42 at a rate controlled by the valve float 44 so as to permit continuous formation of the billet. The billet may be severed by suitable means into appropriate lengths for use in tube extrusion equipment.

While the actual dimensions of the mold and mandrel are not critical, a typical example has been given in the foregoing to emphasize the fact that the product is quite different from a conventional metal tube. It may be said that the outside diameter of the billet should not be less than 6 inches, and the diameter of the opening through the billet should not exceed 3 inches.

What we claim as our invention is:

1. Apparatus for continuously casting a tubular metal billet comprising a cylindrical mold positioned with its axis vertical and having open top and bottom ends, an elongated mandrel located centrally in said mold, means for feeding molten metal into the open top of said mold, and means comprising a float valve having its lower portion immersed in the molten metal adjacent the top of the mold responsive to the level of molten metal in said mold controlling the flow of metal into said mold to maintain the upper surface of molten metal at a substantially constant level therein, mandrel support means extending across the upper open end of said mold, and said float valve has a transversely extending downwardly open channel in which said mandrel support means is received.

2. Apparatus as defined in claim 1 in which molten metal is introduced into said mold from a downwardly open downspout and a valve element on the top of said float movable to close the downspout when the molten metal in said mold reaches a predetermined level.

3. Apparatus as defined in claim 2 in which said float is formed of a relatively light refractory material such as fused silica.

4. Apparatus as defined in claim 2 in which said float has an upwardly open chamber in its upper portion, and flow passages extending downwardly from said chamber to openings in the lower portions of said float.

5. Apparatus as defined in claim 4 in which said float has a flow passage at each side of said downwardly open channel.

6. Apparatus as defined in claim 5 in which said flow passages open into said downwardly open channel.

7. Apparatus as defined in claim 1 in which said mandrel has the outer surface of its upper portion, which spans the level of molten metal in said mold, formed of a refractory material highly resistant to the chemical action of molten oxide slag.

8. Apparatus as defined in claim 7 in which the refractory material is a ceramic or vitreous material such as silica.

9. Apparatus as defined in claim 1 in which the lower portion of said mandrel, which is below the slag containing surface of the molten metal, has its outer surface formed of graphite.

10. Apparatus as defined in claim 9 in which said graphite surface, in the portion of the billet which remains essentially fluid, is cylindrical, and in the portion where the mandrel has solidified and undergoes shrinkage upon continued cooling is downwardly tapered.

11. Apparatus as defined in claim 10 in which the diameter of the lower portion of said mandrel is abruptly reduced at the zone joining the cylindrical and tapered portions.

12. Apparatus as defined in claim 7 in which the lower portion of said mandrel, which is below the slag containing surface of the molten metal, has its outer surface formed of graphite.

13. Apparatus as defined in claim 12 in which said graphite surface, in the portion of the billet which remains essentially fluid, is cylindrical, and in the portion where the mandrel has solidified and undergoes shrinkage upon continued cooling is downwardly tapered.

14. Apparatus as defined in claim 13 in which the diameter of the lower portion of said mandrel is abruptly reduced at the zone joining the cylindrical and tapered portions.

15. Apparatus as defined in claim 1 in which said mandrel is formed of a mandrel rod on which are assembled an upper sleeve of refractory chemically resistant material and a lower sleeve of graphite.

16. Apparatus as defined in claim 1 in which said mandrel comprises an upper tubular sleeve portion extending vertically and located to occupy the zone of the top surface of molten liquid in said mold, said upper sleeve portion being formed of a refractory material highly resistant to the chemical action of molten oxide slag, a lower tubular sleeve portion formed of graphite, said lower sleeve portion having its upper end abutting the lower end of said upper sleeve portion, and an assembly and support rod extending through said sleeve portions, means on said rod supporting the lower end of said lower sleeve portion, said rod being formed of refractory material capable of withstand the temperatures of the melted metal being cast.

17. Apparatus as defined in claim 16 in which said upper sleeve portion is formed of fused silica.
18. Apparatus as defined in claim 16 in which said rod is formed of refractory metal.

19. Apparatus as defined in claim 17 in which said rod is formed of refractory metal.

20. Apparatus for continuously casting a tubular metal billet comprising a cylindrical mold positioned with its axis vertical and having open top and bottom ends, an elongated mandrel located centrally in said mold and having a horizontally extending support strut engaging the upper end of said mold, a downwardly open downspout located above said mold, a vertically movable reservoir and valve body located below said downspout adapted to control flow of melted metal through said downspout and having passages connecting said reservoir to the interior of said mold, said reservoir and valve body having a downwardly open transverse channel in which said strut is received.

21. Apparatus as defined in claim 20 in which said mandrel comprises an upper portion spanning the upper surface of molten metal in the mold and formed of a refractory material highly resistant to the chemical action of molten oxide slag, and in which the lower portion of said mandrel is formed of graphite.

22. Apparatus as defined in claim 21 in which the refractory material is fused silica.

23. Apparatus as defined in claim 21 in which said mandrel portions are tubular sleeves, and comprising in addition a support rod formed of refractory material extending through and interfitting within said sleeves.

24. Apparatus for continuously casting a tubular metal billet comprising a cylindrical mold positioned with its axis vertical and having open top and bottom ends, an elongated mandrel located centrally in said mold, said mandrel comprising an upper portion spanning the upper surface of molten metal in the mold and formed of a refractory material highly resistant to the chemical action of molten oxide slag, and the lower portion of said mandrel being formed of graphite.

25. Apparatus as defined in claim 24 in which the refractory material is fused silica.

26. Apparatus as defined in claim 24 in which said mandrel portions are tubular sleeves, and comprising in addition a support rod formed of refractory material extending through and interfitting within said sleeves.

27. Apparatus as defined in claim 25 in which said mandrel portions are tubular sleeves, and comprising in addition a support rod formed of refractory material extending through and interfitting within said sleeves.

28. Apparatus as defined in claim 24 in which the upper mandrel portion is cylindrical, the upper part of the lower mandrel portion is cylindrical and has a diameter equal to that of the upper mandrel portion, and the lower part of the lower mandrel portion being slightly tapered downwardly to accommodate contraction of the billet as it cools and shrinks.

29. Apparatus as defined in claim 28 in which an abrupt shoulder is provided on the lower mandrel portion at the junction of its upper and lower parts, the shoulder forming an abrupt reduction in diameter of the lower mandrel portion substantially at the zone of solidification of the molten metal.

30. Apparatus as defined in claim 29 in which said mandrel portions are tubular sleeves, and comprising in addition a support rod formed of refractory material extending through and interfitting within said sleeves.
It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 15, first two lines should read:

"Apparatus for continuously casting a tubular metal billet comprising a cylindrical mold positioned with its axis vertical and having open top and bottom ends, an elongated mandrel located centrally in said mold, means for feeding molten metal into the open top of said mold, and means responsive to the level of molten metal in said mold controlling the flow of metal into said mold to maintain the upper surface of molten metal at a substantially constant level therein, said mandrel being formed of a mandrel rod on which are as--"

Signed and sealed this 17th day of December 1974.

(SEAL)
Attest:

McCoy M. Gibson Jr.                                      C. Marshall Dann
Attesting Officer                                        Commissioner of Patents