

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) CONTINUOUS CASTING PROCESS AND APPARATUS

(71) We, TECHNICON INSTRUMENTS CORPORATION, a corporation organised and existing under the laws of the State of New York, United States of America, of 511, BENEDICT AVENUE, Tarrytown, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a process and apparatus for the continuous casting of metal.

In the normal continuous casting of steel, an open water cooled mould is maintained in a fixed vertical position while a billet being cast is withdrawn from below it at a rate determined by thermodynamic conditions. The continuous cast billet is then cut into lengths for further processing.

The elevation required for conventional continuous casting apparatus requires considerable costs for construction to raise the molten steel to a required height.

The continuous casting apparatus of this invention allows the substantial horizontal continuous casting of steel with resulting cost savings. Further the process of this invention may allow for the continuous casting of "rimmed" steel, since sufficient time for the escape of entrained gases may be allowed.

In accordance with one aspect of the invention there is provided a process for continuously casting a metal billet of a length exceeding the length of a cooled closed-end mould into which molten metal is fed from a source, wherein during casting the mould and source are separated progressively to form a solidified casting shell of a billet having a molten core and extending across space produced by the separation, molten metal from the source flowing through said shell of the billet toward the mould during casting.

In a practical embodiment of the invention a closed-end water cooled mould is withdrawn from about a hollow or tubular starting sleeve protruding from a tundish. Molten metal

solidified on contact with the mold side and end walls, but the molten metal is longer in contact with the longitudinally sliding side walls which form a solidified tubular shell about a core of molten metal. As metal solidifies on its brief contact with the end wall of the mould and the mould is withdrawn the thin solidified end wall ruptures and remelts. This continues as the billet is continuously cast.

In accordance with another aspect of the invention there is provided apparatus for continuously casting a metal billet comprising a tundish, a closed-end mould having cooling means, a starting sleeve capable of insertion into the moulds, mounted at or near the pouring outlet of the tundish to receive molten metal therefrom and having a hollow interior through which molten metal flows during casting, and conveyor means for separating progressively the tundish and the mould.

In order that the invention will be understood, it will be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal, vertical section through a continuous casting apparatus at the start of a cast according to this invention;

Figure 2 is a longitudinal, vertical section through a fragment of the exit nozzle of a tundish, a starting bar, a billet in process of being cast, and a differentially cooled mould;

Figures 3 and 4 are longitudinal, vertical sections through modifications of water cooled moulds;

Figure 5 is a longitudinal, vertical section through a mould and a fragment of a billet being cast therefrom, the mould being modified to inject a lubricant therein;

Figure 6 is a longitudinal, vertical section through a mould similar to that shown in Figure 1 and a fragment of a billet being cast therefrom with side walls of the billet being shown sprayed with water on emergence from the mould and with a solidified end wall of the billet being shown therein;

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Figure 7 is a longitudinal, vertical section through the mould shown in Figure 6 and a fragment of the billet being cast therefrom showing the solidified end wall of the billet out of contact with the end wall of the mould prior to rupturing and remelting of the billet end wall;

Figure 8 is a longitudinal, vertical section through a tundish, a billet being cast, and a mould showing a modification of this invention in which a billet is cast at an angle with the horizontal; and

Figure 9 is a side view of a tundish and a longitudinal, vertical section through an unattached starting bar and a fragment of a billet with molten metal shown flowing from the tundish into the upper end of the starting bar as the billet is being cast.

Figure 1 shows a casting ladle 10 from which a hot metal stream 11 flows into tundish 12 which is lined with any suitable heat resisting material 13. Tundish 12 has a stopper rig 14 to allow controlled flow of molten metal 15 through nozzle 16. The tubular or hollow starting bar or sleeve 17 is fixed to nozzle 16 and the starting bar 17 has an outer tapering end 18 containing peripheral grooves 19. The tapering end 18 of starting bar 17 is disposed in the closed end mould 20 which is of copper and water cooled.

Tundish 12 rests on base 19' from which tracks 21 extend to support a mould transport carriage 22 on wheel 23. Carriage 22 has mould 20 resting thereon connected to a mould oscillator 24 by means of rod 25. Carriage 22 is drawn to the right as shown by bar 26 as a billet is cast. Billet supports 27, shown in lowered positions, are raised to support a billet as it is cast and the mould 20 moves to the right. Cooling water 28 enters mould 20 through hose 29 and leaves through hose 30.

Referring now to Figures 1, 6, and 7, a billet 32 is cast in the following manner. Molten steel from tundish 12 flows through the hollow starting bar 17 into the closed end mould 20. Starting bar 17 may be pre-heated to prevent excessive solidification of steel therein which would block further flow of steel through the starting bar. The liquid steel striking the water cooled mould 20 solidifies around the tapered end 18 of bar 17 and adheres to bar 17 assisted by the grooves 19. Holes in or projections from the starting bar may alternately be provided to enable a solidifying steel shell to adhere to it. Chill scrap may also be provided to ensure quick and positive solidification around the tapered end 18 of bar 17.

As soon as the mould cavity 33 is filled with molten steel, the transport carriage 22 and the mould 20 is moved continuously to the right as shown. As may be seen in Figures 6 and 7, a solidified casting shell 34 is formed

with a molten core or centre 35. As the mould 20 moves to the right, molten metal continues to flow from the tundish 12 through the molten centre 35 of billet 32 to be solidified and form casting shell 34 at the end of the billet remote from the tundish 12. A thin end membrane 36 may form as the molten steel contacts the cooled end wall 37 as shown in Figure 6, but further movement of mould 20 away from the tundish 12 will move end wall 37 away from the thin membrane 36 to form a physical gap therebetween, as shown in Figure 7. Molten steel of core 35 will then rupture and remelt membrane 36. The end membrane 36 is in a plastic state and is unable to withstand even the small ferrostatic pressure acting on it. In addition, the mass of membrane 36 compared with the volume of liquid metal in contact with it is very small. The combined effects of this pressure and heat cause the membrane to rupture and remelt almost instantly. Liquid metal will now fill the gap shown between membrane 36 and end wall 37 as shown in Figure 7.

The side walls 38 of mould 20 have a longer sliding contact with the casting shell 34 so that it cools and solidifies to resist ferrostatic pressure. In the arrangement of Figure 6, as mould 20 moves away from tundish 12, nozzles 40 direct a water spray 41 as needed on the casting shell 34. As in conventional continuous casting, the casting shell 34, on solidifying, will shrink away from the mould walls 38. If desired, the mould walls 38 may be tapered slightly toward the open end of mould 20 to more closely follow the shrinkage casting shell 34.

Referring further to Figures 1, 6 and 7, a mould oscillator 24 may be connected to mould 20. During continuous withdrawal of the carriage 22, the mould oscillator 24 acts to withdraw the mould 20 in discrete steps to produce the physical gap between the cooled end wall 37 and the end membrane 36 of solidified steel. The membrane 36 will then rupture as hereinbefore described.

To ensure the continued formation and remelting of the membrane 36, the mould 20 should be oscillated in a particular manner. If it is assumed that the mould transport carriage is being moved away from tundish 12 at a casting rate of 36 inches per minute, the mould should be oscillated at a rate equal to or less than 36 inches per minute for a given number of cycles per second which, for example, could be ten cycles per second. If the mould oscillator 24 moves the mould 20 on carriage 22 at a speed of 36 inches per minute, the mould 20 will remain stationary relative to billet 32 for a short period of time and then move away from tundish 12 with a velocity of 72 inches per second for a short period of time. While the mould 20 is stationary relative to billet 32, the membrane 36 will form.

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When the mould 20 is moved away from tundish 12, the membrane 36 will remelt. The amplitude and period of oscillation of mould 20, if required, may be determined by the length of time required for the formation and remelting of membrane 36. If the mould is oscillated at a rate of more than 36 inches per minute, then during part of the cycle the oscillator would tend to move the mould relatively towards the source, which is obviously undesirable.

Certain empirical formulas have proven to be reasonably accurate to determine the length of time required for a continuously slab or billet of steel to solidify completely. Such a formula for a slab is $T = .17 d^2$ where d is slab thickness in inches and T is time in minutes. Thus a 10 inch thick slab will solidify in 17 minutes. This formula takes into account that a portion of the slab thickness has solidified in a continuous casting mould and that maximum external cooling as by water spray is provided. It is quite reasonable to assume that, with spray cooling applied only where absolutely required, as at the mould exit, and with the continuous addition of heat by the flow of molten metal in the core 35, solidification may be extended well past 60 minutes in core 35 through the length of an ingot or billet being cast according to this invention. Based on the rate of conventional continuous casting speeds, 60 minutes is adequate time to completely empty a ladle of average size. Thus the process of this invention appears to be thermodynamically feasible.

Figure 2 shows a billet 32 having a casting shell 34 and a molten core 35 being cast in a mould 20' having differential cooling therein. Billet supports 27 have been raised to support the length of billet 32 as it is being formed. Water spray nozzles 43 direct a spray 44 on the casting shell 34 as it emerges from mould 20'.

Mould 20' is divided into two water compartments 45 and 46 which cool the mould side walls and a water compartment 48 which cools the end wall 49. Cooling water inlet tube 29' branches into the tubes 50, 51 and 52 which enter the compartments 45, 46 and 48, respectively. By means of the valves 53, 54 and 55 cooling in different portions of the mould 20' may be increased or decreased as required. Water leaving the mould 20' passes through the tubes 56, 57 and 58.

Figures 3, 4 and 5 show modifications of moulds according to this invention. Mould 60 has an end wall 61 which curves smoothly from the side walls 62. Mould 63 has an end wall 64 that is concave. Mould 65 has an inlet passage 66 in its end wall 67 through which a mould lubricant may be injected from tube 67' as mould 63 moves to the right leaving a gap between membrane 36 and mould wall 67.

It is to be noted that when horizontal

continuous casting is carried out according to this invention, the ferrostatic pressure in the casting shell 34 is very low so that the casting shell 34 need only be cooled to solidify sufficiently to contain this low ferrostatic pressure. If billets 12 by 15 inches were continuously cast according to this invention, they should be able to be cast for 100 or more feet in length. On completion of the casting of a billet 32, the mould would be stopped for a period to solidify an end wall 36 of a billet which would be thick enough to resist ferrostatic pressure in the molten core 35. The completed billet would then be further cooled for complete solidification.

It has been particularly difficult for conventional continuous casting apparatus to cast "rimmed" steel because liquid "rimmed" steel is extremely gaseous and the conventional apparatus does not allow for the release of this gas on solidification. This unreleased gas causes imperfections which render the product unusable as high quality sheet after rolling.

As shown in Figure 8, tundish 12' has a stopper rig 14' and an inclined nozzle 16'. From nozzle 16', by means of a hollow starting bar (not shown), a billet 70 is cast at an angle α with the horizontal as indicated by the arrow 72. While continuous casting at an angle with the horizontal increases ferrostatic pressure on the solidified billet wall 73, it allows gases to escape upward.

A further modification is shown in Figure 9 in which a tundish 12'' has a spout 75 which delivers a stream 76 of controlled flow of molten metal 77 into the upper end of an open starting bar 78. The upper end of starting bar 78 may be surrounded by insulation 79 to prevent solidification of molten metal therein. Billet 70 is thus formed as hereinbefore described at an angle with the horizontal to allow the ready escape of gases as when casting "rimmed" steel. Heat may be added to the upper end of the billet 70 after casting to prolong the length of time in which gases may escape from the molten core.

If desired, mould 20 may be spring mounted on carriage 22 to be rapidly jerked away from tundish 12 along billet 32 if the mould seizes momentarily to the billet. The method and apparatus for continuous casting herein described may be applied to other metals than steel, but it will be appreciated the metal must be capable of forming a self-sustaining skin or shell through which molten metal flows during casting.

WHAT WE CLAIM IS:—

1. A process for continuously casting a metal billet of a length exceeding the length of a cooled closed-end mould into which molten metal is fed from a source, wherein during casting the mould and source are separated progressively to form a solidified casting shell of a billet having a molten core, and extend-



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WHAT WE CLAIM IS:—

1. A process for continuously casting a metal billet of a length exceeding the length of a cooled closed-end mould into which molten metal is fed from a source, wherein during casting the mould and source are separated progressively to form a solidified casting shell of a billet having a molten core, and extend-

ing across space produced by the separation, molten metal from the source flowing through said shell of the billet toward the mould during casting.

- 5 2. A process as claimed in claim 1, wherein the mould and the casting source are separated in a continuous manner.

- 10 3. A process as claimed in claim 1, wherein the mould is oscillated so that the mould and the casting source are separated in a step-wise manner.

4. A process as claimed in any of claims 1 to 3, wherein the billet is cast substantially horizontally.

- 15 5. Apparatus for continuously casting a metal billet comprising a tundish, a closed-end mould having cooling means, a starting sleeve capable of insertion into the mould, mounted at or near the pouring outlet of the tundish to receive molten metal therefrom and having a hollow interior through which molten metal flows during casting, and conveyor means for separating progressively the tundish and the mould.

- 20 6. Apparatus as claimed in claim 5, wherein the mould is mounted on said conveyor means for movement away from the pouring tundish.

7. Apparatus as claimed in claim 6, wherein

an oscillator is mounted on the conveyor means and is connected to the mould to oscillate the mould longitudinally in the casting direction during casting.

8. Apparatus as claimed in any of claims 5 to 7, wherein the conveyor means comprises a wheeled carriage.

9. Apparatus as claimed in any of claims 5 to 8, wherein the mould comprises hollow compartments, and the means for cooling the mould comprises means for introducing cooling water into said compartments at different rates to control cooling in different portions of the mould.

10. A process for continuously casting a metal billet substantially as herein described.

11. Apparatus for continuously casting a metal billet substantially as hereinbefore described with reference to Figure 1 or Figure 1 as modified by Figure 2, any of Figures 3 to 5, Figures 6 and 7, Figure 8 or Figure 9 of the accompanying drawings.

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