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HORIZONTAL CONTINUOUS CASTING

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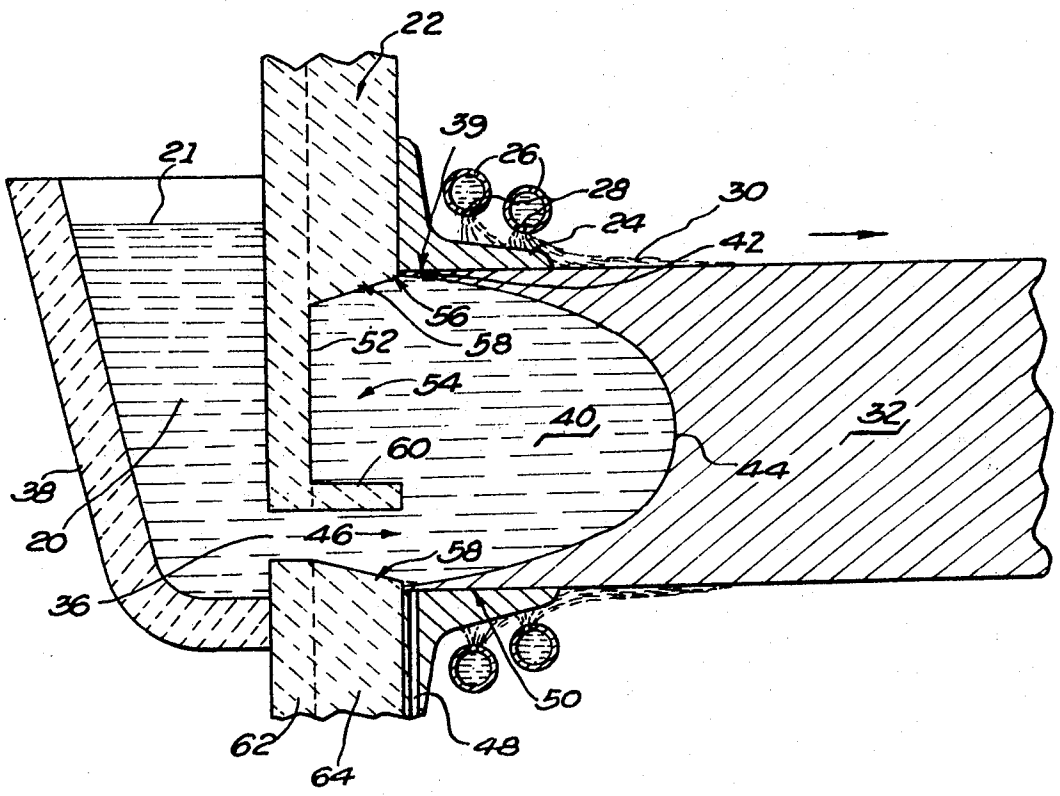

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HORIZONTAL CONTINUOUS CASTING

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ABSTRACT OF THE DISCLOSURE

Horizontal continuous casting of light metal ingots which exhibit improved surface quality especially on the upper ingot surface is obtained by providing a molten metal body extending, in a longitudinal direction, both outwardly from and inwardly into the entrance of a horizontal open ended mold, with molten metal being continuously fed in a stream under the outwardly extending portion of the molten metal body and into the lower portion of the mold entrance so as to supply and maintain the aforementioned body of molten metal, the ingot being continuously solidified and withdrawn from the mold.

This invention relates to the continuous casting of metal ingots in horizontally disposed open ended molds and especially to casting ingots of the light metals, aluminum and magnesium, together with their alloys.

Horizontal continuous casting of light metal ingots has found commercial acceptance because of recognized advantages in certain respects over vertical continuous casting. In the horizontal casting under consideration here, molten metal is provided in a reservoir most often separated from an open ended drastically chilled horizontal mold by a partial barrier having an opening to conduct molten metal from the reservoir to the drastically chilled mold from which the solidifying metal is continuously withdrawn in a horizontal direction.

Commercial use of horizontal continuous casting is, in some cases, hampered by thermal and gravitational effects in that, referring to the molten metal in the mold, the hotter metal tends to rise while the cooler tends to settle downwardly. This results in a non-uniform grain size and structure across the ingot thickness and can also cause surface defects such as laps, tearing, liquation and the like. It is noteworthy that these thermal and gravitational effects severely limit the adaptability to horizontal casting of several measures which are highly successful in vertical casting. One way of alleviating some of these effects is to introduce molten metal into the mold in a relatively thin stream in close proximity to the lower mold inside surface as is described in U.S. Patent No. 3,286,309. While this approach is rather successful in minimizing thermal differences across the ingot thickness or height, defects in the top surface of the ingot are sometimes encountered in certain cases. These defects are generally tear-like in appearance and are particularly pronounced in thick-wide ingots, for instance, those having a cross section of about 16" x 35". This requires the removal of an excessive amount of metal in preparing the ingot for further fabrication operations such as hot rolling. As can be appreciated, an ingot of this size, produced in a horizontal continuous casting operation, is highly useful in fabrication of sheet or plate products and any surface defetcs which result in a large amount of scrap removal are costly in a commercial operation.

Accordingly, it is an object of this invention to provide for the horizontal continuous casting ingots which exhibit improved surface quality, especially on the top surface.

Another object is to provide a method and apparatus, especially useful in producing large size ingots wherein molten metal is fed in a thin stream in close proximity to the lower mold inside surface and wherein provision is made to alleviate tearing defects on the upper ingot surface.

Other objects of the invention will, in part, be obvious and will, in part, appear hereinafter in this description and the drawing in which:

The drawing is an elevation view, partly in cross-section, illustrating the invention.

Briefly, the invention contemplates providing a body of molten metal extending both outwardly from and inwardly into the entrance of a horizontal mold and feeding molten metal in a stream under this body into the lower portion of the entrance of the mold to maintain the molten metal body. The stream is preferably relatively thin and in close proximity to the lower mold wall but separated from the aforementioned extending body of molten metal. Within the mold molten metal is solidified to provide at least the exterior of an ingot which is continuously withdrawn from the mold.

Referring to the drawing, there is shown schematically a horizontal casting apparatus wherein molten metal reservoir **20** is provided on one side of an insulating closure **22**. On the opposite side of the closure is a horizontally disposed mold **24** which is chilled by suitable cooling means such as water pipes or headers **26** provided with holes **28** to permit spraying water **30** against the surfaces of the mold and, in most cases, the ingot **32** emerging therefrom. An opening **36** is provided in the closure **22** for the passage of liquid metal from the reservoir **20** to the chilled mold. The reservoir is confined by suitable insulating members **38** and the molten metal surface **21** is maintained at a higher elevation than the upper inside surface **39** of the mold, such that any liquid metal **40** within the mold **24** is under a positive liquid metal head. Within the mold, a relatively thin embryo ingot surface skin **42** is almost immediately formed by the liquid metal as it is chilled by the drastically chilled mold surface. This skin thickens as the ingot progresses outwardly from the mold as indicated by ideal solidus line **44**. Not shown are suitable support structures for the elements described and some means of continuously withdrawing the solidified ingot, such as a power endless belt or the like.

As is shown, the gate opening **36** introduces molten metal in a relatively thin stream **46** which enters the mold in close proximity to the lower mold inside surface **50**, substantially in accordance with the aforementioned U.S. Patent No. 3,286,309.

This tends to compensate somewhat for the inherent tendency to establish a thermal gradient across the ingot thickness or height since the hotter metal entering the mold here tends to compensate for the tendency for the cooler molten metal to settle. In accordance with the invention, upper surface tearing is alleviated by the provision of recess **52** in closure **22**. This facilitates the provision of molten metal body **54** extending both outwardly from and inwardly into the mold entrance. The opening described by the recess, i.e. the lateral dimensions of body **54**, are slightly smaller than the mold opening which provides a ledge or abutment **56** extending inwardly about $\frac{1}{16}$ to $\frac{1}{8}$ inch from the mold inside surface **39**. The lateral boundary of the recess is preferably tapered so as to diverge into the mold. The taper can vary up to 45° although tapers from 15 to 25° are preferred. For example, in the embodiment shown a tapered surface **58** of 20° is utilized. Shelf member **60** is provided to separate the outwardly extending portion of molten metal body **54** from stream **46** which feeds and maintains body **54**. Concerning the dimensions of the recess, shelf, and gate opening, the recess should be deep enough to provide

a body 54 of significant size, i.e. having a significant projection outwardly from the mold entrance. Generally a depth of ½ inch or more is adequate. If the recess is too deep, stream 46 becomes excessive in length and maintaining proper molten metal temperature may become troublesome. A depth of two or three inches is very effective.

The thickness of the shelf member 60 is not critical and the extent to which it protrudes toward the mold entrance can be varied within the practice of the invention. Generally it is preferable to have the shelf protrude or extend to the mold entrance. Further extension or protrusion into the mold can offer some advantage although such may introduce problems in commencing a casting run since the protruding shelf may interfere with the starting block or plug which closes the mold at the start of a casting run.

The shelf member 60 traverses substantially the entire ingot width as does, in many cases, the gate opening 36. As already mentioned, the gate opening is advantageously contoured to conform to the contour of the lower inside surface 50 of the mold in accordance with the teaching of U.S. Patent No. 3,286,309. When such is provided, it is also often advisable to similarly contour the shelf member 60 so as to properly separate molten metal body 54 from stream 46, especially where the contour is rather pronounced such as that depicted in the copending application for a round ingot. In this case, it is advantageous to have the shelf member describe a circular arc in traversing the width of the mold opening. However, where the gate contour is very slight or traverses the mold width in a substantially horizontal path, the shelf member may likewise assume a substantially straight horizontal disposition.

In the embodiment shown, the recess 52, gate opening 36 and shelf 60 are all fashioned by machining, or otherwise removing material from heat insulative barrier member 22. However, it will be generally more convenient to fashion such by providing separate pieces 62 and 64, the former being closed except for the small gate opening 36 and the latter being almost entirely open. Shelf 60 is then provided as a separate piece joined to member 62.

In practicing the invention, it can be seen that a molten metal reservoir 20 is conveniently maintained adjacent an open ended chilled horizontal mold. Molten metal is fed from the reservoir to the lower portion of the entrance of the mold under the outwardly extending portion of molten metal body 54 to supply and maintain molten metal body 54. The molten metal is fed in a stream which is relatively thin and preferably is in close proximity to and contoured in general conformity with the mold lower inside surface 50. The molten metal body 54 generally has lateral dimensions smaller than that of the mold opening and is separated from the thin molten metal feed stream 46 by a heat insulative barrier, conveniently provided by shelf 60. When the molten metal enters the mold, the surface portions are almost immediately solidified to provide at least the surface portions of the ingot which is continuously withdrawn from the mold. It is believed that the heat insulative barrier, or shelf, 60 serves several functions. First, it separates the molten metal feed stream 46 from molten metal body 54. Second, it directs the stream into the mold cavity rather than into the portion of body 54 which extends into the mold. It is believed that these effects combine to somehow alleviate the tearing which occurs on the upper surface of the ingot which may be caused by rapidly rising hot molten metal penetrating the thin embryo ingot shelf. However, the exact mechanism by which the practice of the invention alleviates upper surface tearing is not fully understood and this explanation is only offered to illustrate and not necessarily limit the invention.

In practicing the invention, some provision is preferably included for continuously introducing lubricant in the vicinity of the mold entrance to minimize any binding

of the ingot to the mold surfaces. Again reference is made to aforementioned U.S. Patent No. 3,286,309, which illustrates suitable means for providing such. Accordingly, a plurality of radially disposed channels 48 can be provided to furnish lubricant to the mold inner surface and the molten metal surface. It is also preferable to provide a short initial mold portion having an opening slightly smaller than that of the balance of the mold such as depicted in copending application Ser. No. 542,424, filed Apr. 13, 1966, and now Patent No. 3,381,741.

As an example illustrative of the practice of the invention, ingots were cast of aluminum alloy 5082 (Al, 4.5% Mg) and 5086 (Al, 0.45% Mn, 4.0% Mg and 0.1% Cr). The ingots produced were continuous slabs measuring 12" x 38" or 16" x 40" in cross section. The casting procedure and apparatus employed was substantially that illustrated in FIGURE 1 and described above. In each case, the metal feed opening 36 measured one inch across and traversed substantially the full width of the mold opening. The recess 52 in closure 22 was 2 inches deep and tapered surfaces 58 had an angle of 20°. The shelf 60 extended 2 inches so as to coincide with the mold entrance. Several ingots were cast in this fashion and all exhibited substantial freedom from tearing or liquation on their upper surfaces.

While the above description has illustrated preferred embodiments of the method and apparatus in accordance with the invention, such is not necessarily intended to restrict the scope of the claims appended hereto which are intended to encompass any practice as falls within the true spirit of the teaching set forth herein.

What is claimed is:

1. A method of continuously casting light metal ingots in a horizontally disposed, open ended, chilled mold comprising:

(1) providing a body of molten metal extending longitudinally both outwardly from and inwardly into the entrance of said mold, the lateral cross section of the outwardly extending portion of said body being smaller than the mold opening,

(2) continuously feeding a stream of molten metal under the outwardly extending portion of said body of molten metal and into the lower portion of the entrance of said mold to supply and maintain said body of molten metal,

(3) continuously solidifying at least the exterior of the molten metal within said mold to initiate formation of an ingot, and

(4) continuously withdrawing the ingot from said mold.

2. A method of continuously casting ingots of aluminum or alloys thereof in a horizontally disposed, open ended, chilled mold comprising:

(1) providing a body of molten metal extending longitudinally both outwardly from and inwardly into the entrance of said mold, the lateral cross section of the outwardly extending portion of said body being smaller than the mold opening,

(2) continuously feeding a relatively thin stream of molten metal under the outwardly extending portion of said body of molten metal and into the lower portion of the entrance of, and in close proximity to the lower inside surface of, said mold to supply and maintain said body of molten metal, said stream being separated from said outwardly extending portion by a heat insulative barrier,

(3) continuously solidifying at least the exterior of the molten metal within said mold to initiate formation of an ingot, and

(4) continuously withdrawing the ingot from said mold.

3. A method of continuously casting ingots of aluminum or aloys thereof in a horizontally disposed, open ended, chilled mold comprising:

(1) providing a first body of molten metal adjacent the entrance of said mold but separated therefrom by a

heat insulative barrier having an opening therein for the passage of molten metal from said first molten metal body to said mold and maintaining the upper surface of said first molten metal body above the upper inside surface of said mold,

(2) providing a second body of molten metal extending longitudinally both outwardly from and inwardly into the entrance of said mold, the lateral cross section of the outwardly extending portion of said second body being smaller than the mold opening,

(3) continuously feeding a relatively thin stream of molten metal from said first body of molten metal, under the outwardly extending portion of said second body of molten metal and into the lower portion of the entrance of, and in close proximity to the lower inside surface of, said mold to supply and maintain said second body of molten metal, and

(4) continuously solidifying at least the exterior of the molten metal within said mold to initiate formation of an ingot, and

(5) continuously withdrawing the ingot from said mold.

4. Apparatus for the continuous casting of light metal ingots comprising:

(1) a chamber for holding a first body of molten metal,

(2) a chilled, open ended horizontal mold adjacent thereto,

(3) a heat insulative closure extending across the entrance of said mold, and having

(a) a molten metal feed opening in the lower portion thereof for passage of a stream of molten metal from said first body into said mold, said opening being relatively thin and disposed in close proximity to the lower mold inside surface, and

(b) a recess extending outwardly of the entrance to said mold, said recess being laterally bounded by a surface of said closure in substantial

conformity with the mold inside surface and spaced slightly inwardly thereof, except where said recess communicates with said metal feed opening, where it is bounded by a heat insulative barrier separating said recess from said opening, and

(4) means for chilling said mold with liquid coolant.

5. Apparatus for the continuous casting of light metal ingots comprising:

(1) an open ended mold having a horizontal axis and an entrance and exit,

(2) means to provide a body of molten metal extending longitudinally outwardly from and inwardly into the mold entrance the outwardly extending portion of said body having a lateral cross section smaller than the mold opening,

(3) means to feed molten metal into the mold entrance, said means being so constructed and arranged as to feed molten metal under said outwardly extending body of molten metal and into the mold entrance.

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