A water-cooled sliding mold for the electro slag remelting of a billet with a slag layer covering the billet is made of a relatively large cross section tubular member which includes an upper part having substantially smooth constant cross section, a middle part having a substantially smooth downwardly diminishing cross section and a lower part having an irregular cross section which includes inwardly extending portions at spaced locations around the periphery which extend below the smallest cross section of the middle part. The construction is such that the slag becomes separated from the metal at the beginning of the inwardly extending portion of the lower part of the mold. The lower part advantageously includes a wave-like formation which projects into the mold interior which act to crush the slag shell and the slag fragments fall down off the mold. The cooling of the billet and the removal of the slag particles is also improved by circulating a cooling medium in the lower part of the mold.

8 Claims, 1 Drawing Figure
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WATER-COOLED SLIDING MOLD FOR ELECTRO SLAG REMELTING

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to the construction of molds and, in particular, to a new and useful water-cooled sliding mold with a large cross section for the electro slag remelting of a billet with a slag layer covering the billet and which includes a mold having a lower portion with inwardly extending parts at spaced locations around the interior circumference which extend inwardly below the smallest cross section of the remaining portion of the mold and provide a means for removing the slag fragments from the metal being formed and for facilitating the cooling of the metal from the mold.

2. Description of the Prior Art

As is well known, the surface of a billet which is remelted on the slag is covered with a slag shell in which the remelted billet solidifies and cools down. With the continuing growth of the billet during the remelting process, the slag jacket also grows in size. When remelting billets using a water-cooled sliding mold, either the billet or the mold are vertically advanced. During this motion, the slag covered surface of the billet and the inner lining of the mold move in respectively opposite directions. The metal billet shrinks down during its solidification throughout its cross section and subsequently cools. The solidified slag has a smaller shrinkage factor than the remelted metal so that the jacket separates from the billet surface and forms an air gap therebetween. With billet diameters up to approximately 1500 mm, the gap widths produced between the mold and the slag jacket as well as between the slag and the billet, are relatively small. However, when the billet diameters exceed 2000 mm, gaps of considerable width appear which, as experience shows, is in the range of from 10 to 20 mm. Thus, with large billet diameters the width of the gap between the slag jacket and the billet may be such that when the still molten billet sump happens to break through the solidified skin of the billet, the metal cannot be stopped and the sump flows out. With billet diameters of about 3000 mm some 30 to 40 tons of molten metal may thus run out of the billet being formed.

The risk of a break-out in billets of large diameters, is great particularly because of the formation of the air gap between the metal and the slag jacket or between the slag jacket and the remelted billet so that the heat removal is strongly hindered by the insulating action of the air. Relatively thick slag layers on the billet surface, which are usual with large diameter sizes of billet, are particularly susceptible to such air gaps. Convective currents of air hardly appear in such gaps especially between the billet and the slag so that the heat is not removed in sufficient quantities. This means that in the solidified exterior zone of the billet, an accumulation of heat takes place during which a part of the metal, which is already solidified, becomes melted again. This phenomenon, which occurs above all when large billet diameters having an unfavorable volume to heat emission surface ratio are employed, and it leads to break-outs of molten steel from the remelting sump. Such undefined irregular conditions of solidification, even if they do not result in a break-out of molten metal, are disadvantageous in that the structure may be distorted by liquation and other irregularities after solidification.

SUMMARY OF THE INVENTION

The invention is based on the provision of a water-cooled sliding mold for casting large billets in an electro slag remelting process which operates satisfactorily while safely preventing a break-out of molten metal through the skin of the billet which is already solidified and which permits the billet to be drawn off without trouble and may be operated with definite cooling conditions so that the formation of a flawless structure almost free of liquation is assured.

The invention provides a mold which is provided with an upper part having a constant smooth cross section, a middle part having a smooth cross section which diminishes downwardly, and a lower part having an irregular cross section which diminishes inwardly at different places below the smallest cross section of the middle part. In the regular and smooth-lined upper part of the mold, the billet and the surrounding slag layer are remelted and solidify on their periphery. In the downwardly tapering middle part of the mold, the wall of the mold follows the shape of the slag layer which is contracted by cooling and also acts as a support for the slag and the billet skin still applied thereto. The lower part with the irregular cross section, which is located in the zone where the slag layer begins to separate from the billet skin, crushes the slag cover by means of inwardly projecting portions of its cross section so that the fragments of the slag layer fall down off the mold. Owing to the fact that in its lower portion the billet surface is separated from the slag layer, its cooling is increased and there is no danger of the skin being melted by still molten inner parts of the billet. The rapid and definite cooling in this zone reduces the depth of the sump and improves the quality of the billet structure with respect to liquation.

Owing to the fact that the continuous reduction of the cross section in the middle part of the mold only equals or slightly exceeds the thermal shrinkage of the slag layer on the billet surface, a reliable support is obtained in the middle part and also the slag jacket is prevented from clinging to the mold. In such a case, the lining of the mold could be damaged because the advance is forced by the continuing remelting process. A safe crushing action on the slag is produced by the inwardly projecting portions of the lower part of the mold and a better cooling is obtained for this section to ensure against a possible break-out of the molten metal and a rapid solidification of the metal is ensured.

For the remelting of cylindrical billets, it is advantageous to use a mold having a circular cross section and a lower part which has a wave-shaped interior surface and is slightly conical and wherein the wave crest lines are in contact with the billet surface which, owing to its thermal shrinkage, is also slightly conical. This shape of the mold can easily be manufactured. It assures a good cooling of the lower part of the billet and the smooth surface of the almost vertically extending channels formed between the wave portions, both of which extend substantially axially of the mold. The vertically extending channels assure the falling down and removal of the crushed slag. It is also possible to provide additional knubs and/or slag breakers in the zone of the slag crushing, i.e. at the upper end of the lower part of the mold.
A large flexibility in respect to cooling conditions is obtained by providing a separate cooling system for the lower part of the mold. It is also advantageous to make the lower part of the mold, which is particularly exposed to strain by the crushing and guiding of the slag of a wear-resistant material such as hematite. A simple robust and easily exchangeable construction of the lower part is a single wall structure without a cooling system because the lower part of the mold comprises the vertically extending passages formed between inwardly extending wave portions. Air or perhaps a cooling or protective agent may be blown against the billet surface, so that the cooling may be controlled in the removable of the slag promoted.

The features of the invention may be applied to the casting of all sorts of large billets which are manufactured in the electro slag remelting process such as cylindrical, rectangular, polygonal and similar shapes in particular. The conicity of the middle part, which must be adapted to the contracting and solidifying slag jacket, depends on the composition of the slag, the speed of the remelting operation in the advance of the billet and the temperatures. It may be determined by simple operational tests. The same applies to the lower portion of the sliding mold in which a reliable crushing of the slag up to the billet surface must be assured by providing projecting portions which extend so as to contact the surface of the billet. The formation of the lower portion of the mold must be such that the inwardly extending portions are sized to take into account the shrinkage of the billet and the size of the passages to facilitate the falling slag fragment removal.

Accordingly, it is an object of the invention to provide a water-cooled sliding mold particularly for the electro slag remelting of relatively large diameter billets with a slag layer covering the billet, which comprises a tubular mold having an upper part with a substantially constant smooth cross section and middle part with a substantially smooth downwardly diminishing cross section and a lower part having an irregular cross section which includes inwardly extending portions disposed around the interior circumference below the smallest cross section of the middle part.

A further object of the invention is to provide a water-cooled sliding mold which is simple in design, rugged in construction and economical to manufacture.

For an understanding of the principles of the invention, reference is made to the following description of a typical embodiment thereof as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

The only FIGURE of the drawing is a cross sectional view of a water-cooled sliding mold with a remelting electrode and a remelted billet and constructed in accordance with the invention.

GENERAL DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, in particular, the invention embodied therein, comprises a tubular mold generally designated 50 for the electro slag remelting of large diameter billets with a slag layer covering the billet during the operation. The water-cooled sliding mold is used for remelting a billet 1 in an electro slag process with a covering slag layer 2. The water-cooled mold 50 comprises an upper portion or part 3 having a constant smooth cross section, a middle part 4 having a smooth downwardly diminishing cross section and a lower part 5 having an irregular cross section. The cross section of the lower part 5 is reduced at spaced locations around its inner circumference by wave-like projections 6 which extend inwardly beyond the smallest diameter of the middle part 4. The wave-like formations 6 form undulations which extend approximately in an axial direction of the mold and they form spaces therebetween.

The upper mold part 3 and the middle mold part 4 are provided with a common water-cooling system which comprises a double wall cooling jacket defining a cooling space 52 for the circulation of a cooling medium which is circulated through an inlet 7 and out through an outlet 8.

The lower part 5 of the mold, has a separate cooling circuit which includes a double wall formation forming a space 54 for the circulation of the cooling medium through an inlet 9 and out through an outlet 10. The lower part 5 is also provided with a cooling gas connection in the form of an inlet 11 and an outlet 12.

While remelting a fusible electrode 13 by immersing it into the slag 2, the slag is drawn off as a shell along with the billet 1. Both the slag shell and the billet shrink down during the solidification. The inner wall of the middle part 4 of the mold is adapted to this shrinkage. Owing to the greater thermal shrinkage of the metal, the slag shell 2 becomes separated from the billet 1 at the location 14. In the course of advance, the wave-like projections 6 which extend inwardly from the lower part 5 to the billet skin and they crush the slag shell and the slag fragments 15 fall downwardly off the mold. The cooling of the billet and the removal of the slag particles 15 may be improved by introducing a compressed air/water mixture through the connections 11 and 12.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A water-cooled sliding mold for the electro slag remelting of a billet of relatively large cross section using a slag layer which covers the billet, comprising a tubular mold having an upper part with a substantially constant smooth cross section, a middle part having a substantially smooth downwardly diminishing cross section, and a lower part having an irregular cross section which includes inwardly extending portions at spaced locations around the interior circumference which extend inwardly below the smallest cross section of said middle part.

2. A water-cooled sliding mold, according to claim 1, wherein the diminution of the cross section of said middle part is, at most equal to the shrinkage of the slag layer.

3. A water-cooled sliding mold, according to claim 1, wherein said inwardly projecting portions of said lower part extend up to a contact with the billet skin.

4. A water-cooled mold, according to claim 1, wherein said mold has a circular cross section and its lower part is provided with undulations which are approximately parallel to the mold axis, the crest lines of the undulations contacting the slightly conical billet along the generating lines thereof.

5. A water-cooled mold, according to claim 1, wherein said lower part includes a separate cooling sys-
5. A water-cooled mold, according to claim 1, wherein the lower part includes a wall made of material resistant to mechanical abrasion.

6. A water-cooled mold, according to claim 1, wherein said lower part includes an outer jacket with said projections extending inwardly from said jacket and including a connection extending from the exterior of said outer jacket into the space between said projections.

7. A water-cooled mold, according to claim 6, wherein said resistant material is hematite.

8. A water-cooled mold, according to claim 1,