Aug. 22, 1967 T. W. RATCLIFFE 3,336,973

CONTINUOUS CASTING MOLD

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FIG. 2

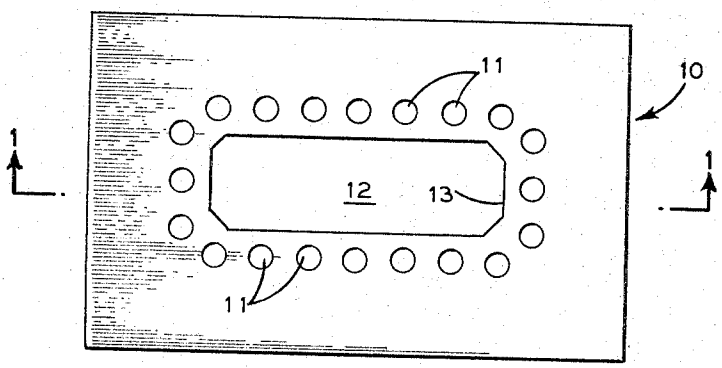
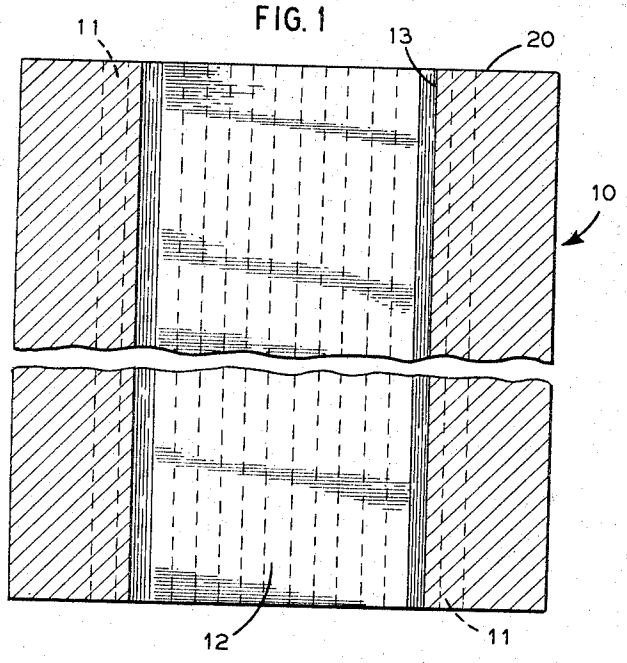


FIG. 1



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FIG. 3

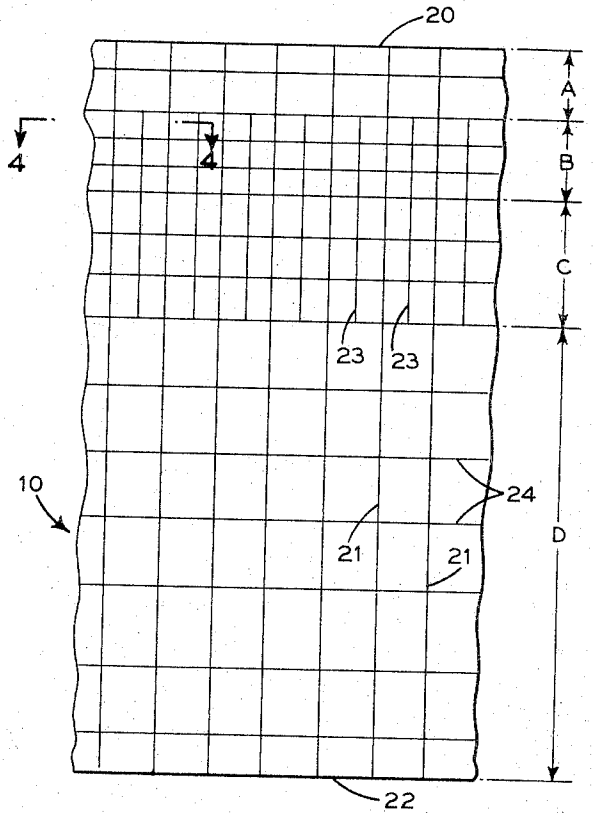
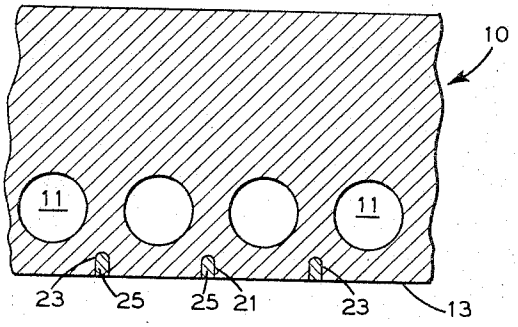


FIG. 4



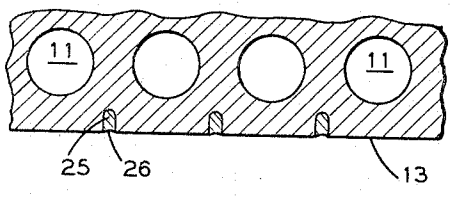


FIG. 5

United States Patent Office 3,336,973 Patented Aug. 22, 1967

3,336,973

CONTINUOUS CASTING MOLD

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5 Claims. (Cl. 164—283)

The present invention relates to the continuous casting of metals and more particularly to an improved construction of fluid cooled molds utilized in the casting of high melting temperature metals.

In the continuous casting of metals an upright open ended fluid cooled mold is arranged to receive a stream of molten metal at its upper end within an embryo casting withdrawn from its lower end. In solidifying a shell of solid metal on the casting, the heat of solidification, i.e. the heat that must be abstracted from the metal being cast to initiate and continue solidification, must be transmitted to a cooling fluid passing through flow passageways formed in the mold walls. In the usual continuous casting unit the cooling fluid consists of water which is passed through the flow passageways in sufficient quantity to obtain the necessary cooling rate. Thus in the operation of continuous casting molds there will be a temperature difference between the hot face of the mold wall and the relatively cool face of the wall adjacent the cooling fluid flow passageways. While the mold wall temperature difference will be substantially the same at any selected level in the mold, i.e. in a plane normal to the axis of the mold cavity, the hot face temperature of the mold will be different at different points axially spaced along the mold cavity from a maximum value adjacent the zone of the molten metal level in the mold.

In the usual continuous casting unit the cooling water is passed through the mold cooling fluid flow passageways in sufficient quantity to maintain a water leaving temperature of the order of 7 to 15° F. above the entering water temperature. When casting steel, for example, the hot face of the mold in the zone of maximum temperature will be of the order of 500 to 600° F. above the cooling water temperatures.

Most continuous casting molds for large squares and slabs are constructed of three general types. One of the types has involved the formation of the desired mold cross-sectional cavity by machining in a solid block of metal, such as copper. In this type of mold the cooling fluid flow passageways have been drilled through the block parallel to and spaced from the inner hot face of the mold. The location and number of these drilled molds, relative to the mold hot face, is predicated on the thermal properties of the metal from which the mold is made.

Another type of mold is constructed of heavy copper blocks with the cooling fluid flow passageways drilled therein, as in the solid block type, with several of the copper blocks assembled in a restraining container to define the mold cavity.

The third type of mold construction has utilized relatively thin plates or liners of metals having high thermal conductivity, such as copper or brass, or the like, where the plates or liners are backed up by and supported from massive steel members. In this type of mold the cooling fluid flow passageways are usually formed longitudinally of the mold with intermediate supporting fins projecting inwardly from the container and attached to the liners. Several of such plate assemblies are assembled to define the mold cavity. In all types of mold construction the temperature difference transversely of the mold wall and longitudinally of the mold causes expansion difficulties which limit the life of the mold. In the known block type of mold, the difficulties take the form of stressing the

hot face of the mold beyond its strength limits so that the mold must be periodically removed from operation and remachined to remove the fatigue cracks from the confining wall of the mold cavity. Such difficulties are caused by the tendency of the hot face of the mold to expand in both lateral and longitudinal directions to a greater extent than the cold face of the mold. The one-piece construction of the mold restrains lateral movement in particular, thus stressing the hot face of the metal beyond its elastic limit in at least the highest temperature zone of the mold. In the other types of mold the same effects may be found provided the lateral ends or the intermediate fins of the walls are restrained by the container supporting the mold walls. In addition, difficulties are encountered at the joints between the abutting edges of the mold walls. It will be understood in this connection that the lateral expansion of each mold wall will be greatest in the hot zone of the mold. If the corners of the mold walls are fully restrained the metal of the mold wall will attempt to form a convex configuration stressing the mold so as to reach a stress value leading to premature termination of the casting operations. If the corner restraining forces are such as to permit expansion in the hot zone a gap will be formed in the corners both above and below the hot zone of the mold wall. In such circumstances any gap in the joints tends to be filled with the metal being cast, which can lead to a failure in the continuous casting operation by freezing in the mold gaps or by further deformation of the mold wall due to the metal frozen in the gaps.

In the present invention, I provide a plurality of slots machined inwardly from and extending the full length of the hot face of the mold and to a desired depth having at least sufficient lateral dimension to compensate for thermal expansion of the mold hot faces. Each of the slots machined in the hot face of the mold is preferably filled with a metallic material having greater ductility than the face material of the mold which permits thermal expansion of the material between the slots without overstressing the material therebetween. Advantageously, the inserts have been formed from the noble metals, such as gold, silver, or platinum or alloys of these metals. One of the most desirable materials for use in the inserts is fine or high purity silver which is sufficiently ductile to meet the requirements of the service indicated, has a high thermal conductivity, and is easily fused to the mold wall metal. The characteristics of the silver include an exceptionally high thermal conductivity and a tendency to anneal itself at room temperatures after use at the high temperatures prevailing in an operating continuous casting mold.

Alternatively, the walls in the segmented mold type of construction may be formed with silver inserts or leaves, for example, extending through the mold wall so as to form a sandwich type of wall structure. Such walls may be formed by rolling or forging. As a further alternative, depending at least in part on the mold wall dimensions, the ductile metal inserts or leaves may be located only or additionally at the corners of the mold assembly.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part oft his specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

FIG. 1 is an elevation, in cross-section, of a continuous casting mold;

FIG. 2 is a horizontal plan view of the mold shown in FIG. 1;

FIG. 3 is an enlarged vertical view of a portion of the interior surface of a mold wall of the type shown in FIG. 2;

FIG. 4 is a further enlarged cross-section of a segment of the mold shown in FIG. 3 taken on the line 4—4; and

FIG. 5 is an alternative form of mold construction to that shown in FIG. 4.

In the illustrated embodiment of the invention, the mold is usable in a continuous casting unit such as shown in U.S. Patent No. 2,590,311. The particular mold shown is formed from a block of metal, such as copper, where the mold cavity is machined in the block with the cross-sectional configuration desired. As shown, the cross-section of the cavity is generally rectangular with bevelled corners where the length of the mold cavity is greater than that of the width.

It will be appreciated that in accordance with the principles of the present invention, the mold could be constructed in the manner disclosed and claimed in U.S. Patent No. 2,867,018, where the confining walls of the mold are formed from relatively thin plates of copper or brass, backed by a massive steel casting. Either form of mold construction, i.e., a so-called block type or the plate type, is equally applicable to the use of the present invention.

Referring to FIGS. 1 and 2, a block type mold **10** having a rectangular cavity **12**, is provided with a plurality of substantially equally spaced fluid flow passageways **11** extending throughout the length of the mold, with each passageway substantially uniformly spaced from the hot face **13** of the mold wall.

In such a construction, the mold may be positioned with its axis vertical and when casting steel the hot face **13** of the mold will be contacted by molten metal at a temperature of the order of 2700° F., while the cooling fluid passing through the passageways **11** may be of the order of 50° F. The temperature gradient between the hot inner surface or face **13** which may be at a temperature of 500° F. and the cooling flow passageways **11** will follow the usual temperature gradient characteristics, with the hotter portions of the mold walls being subjected to higher thermal expansion stresses than the relatively cooler portions. It will also be understood the temperature gradation longitudinally of the mold will vary from a maximum in the zone of initial molten metal contact with the mold walls to a minimum adjacent the lower casting discharge end of the mold. The reduction in the rate of heat transfer in the lower zone is due to shrinkage of the casting from the mold walls with the imposition of an insulating gap between the casting and the confining mold surface.

As shown in FIG. 3, the length of the mold may, for convenience, be divided into a plurality of zones which are exposed to different rates of heat transfer. The uppermost zone A extends downwardly from the upper edge **20** of the mold cavity to a position approximately that of, or immediately above, the upper level of the molten metal pool maintained in the mold. Since the molten metal is usually poured into the upper end of the mold cavity, the walls in this zone will obtain heat by radiation upwardly from the meniscus of the molten metal pool and from the incoming stream of metal.

It will be appreciated the level of the molten metal in the mold cavity is not usually fixed and will vary somewhat even when the operator intends to maintain such level at a constant value. The great majority of continuous casting units deliberately vary the molten metal in the mold either by cyclic reciprocation of the mold itself or by variation in the rate of casting withdrawal from the mold. Also, an exact coordination of the pour rate with the casting withdrawal is improbable when casting steel due to the erosive and corrosive character of molten steel in contact with the refractories defining the metal flow path to the mold. Thus the lower limit of zone A, and the upper limit of the adjoining zone B, cannot be exactly at the level of the molten metal pool in the mold cavity.

The zone B comprises that portion of the mold wall in direct contact with molten metal and transmits the highest heat flow to the cooling fluid. The zone C, immediately below zone B, is located in that portion of the mold where the casting has a thin shell of solidified metal and is beginning to shrink away from contact with the mold wall. Heat transfer to the mold wall will, however, be relatively high since the solidified casting shell is weak in this area and may reheat and expand to reestablish contact with the wall of the mold. The lowermost zone D will have a relatively low heat exchange rate between the wall and the casting due to the normal formation and maintenance of an "air gap" between the casting and the wall of the mold.

In accordance with the invention, the hot face of the mold wall is slotted to a desired depth dependent upon the type and design of mold utilized. The width of the slot need only be enough to permit substantially unrestrained expansion of each preselected unit in a pattern. For example, if the slots are made on one inch centers, they should be wide enough to allow free linear expansion of the intervening inch of mold metal up to its operating temperature. Assuming the hot face of the mold to be 500° F. to 600° F. above the water cooled face of the mold, the slot width for copper or 85–15 brass would be of the order of four to five thousandths of an inch (.004 to .005). The machining of a slot of this width is difficult, if not impossible, and I select a slot width that is machinable, such as ten to twenty thousandths of an inch and fill the slot with a ductile strip or filler so that expansion of the mold wall can occur, and the metal being cast will not "key" in the slots and disrupt casting operations.

In the portion of the mold **10** shown in FIGS. 3 and 4, slots **21** are machined in the inner surface of the mold wall and extend from the upper edge **20** to the lower edge **22** of the mold. The slots **21** are parallel to each other and to the longitudinal axis of the mold. In the embodiment shown the slots **21** are two inches apart with shorter slots **23** machined in parallel with and between the slots **21**, in the zones B and C only. Similar slots **24** are machined in the mold wall transversely of the mold axis and throughout the periphery of the mold. In the zone D the slots **24** may be further apart than in the other zones, being closer in zone B than in either zone A or C. The spacing of the slots is dependent upon the amount of thermal expansion expected in the mold wall in different zones.

As shown particularly in FIG. 4, the slots **21** and **23** are machined approximately one-half the depth of the wall between the hot face **13** and the adjoining surface of the fluid flow passageway **11**. In the example shown, the depth of each of the slots is approximately 3/16". All of the slots are approximately of the same depth and width. Preferably the slots are filled with fine silver to form the inserts **25** where the inserts are brazed or otherwise attached to the metal of the mold wall for good thermal contact therebetween.

In the described construction, the thermal distortion of mold walls is substantially reduced particularly in the region of highest temperatures. In addition, the temperature changes and mold flexing at the bottom of the slots occur where the temperature differences are of lesser values relative to the hot surface of the wall and where the materials have better fatigue properties, thereby resulting in a decidedly improved mold service life.

In operation, as the mold wall is heated, differential thermal expansion occurs and the inserts **25**, being more ductile than the material of the wall, will be compressed without overstressing the material of the wall. During compression of the inserts **25**, some of the metal thereof will be displaced beyond the surface **13** of the mold, but the displacement will be minor and will not ordinarily interfere with the casting operations. However, under some unusual circumstances it may be desirable to indent the surface of the insert as shown in FIG. 5. In such cir-

cumstances the surface **26** of the insert will be grooved or cut to form an inwardly curved surface when the mold is at ambient temperatures so that at operating temperatures the surface of the insert will be substantially flush with the surface **13** of the mold. The maximum depth of the curved surface **26**, when cold, need be only a few thousandths of an inch.

While in accordance with the provisions of the statutes there is illustrated and described herein a specific embodiment of the invention, those skilled in the art will understand that changes may be made in the form of the invention covered by the claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of the other features.

What is claimed is:

1. A continuous casting mold comprising walls defining an open ended cavity to receive molten metal delivered to one end and to discharge an embryo casting from the opposite end thereof, means defining cooling fluid flow passageways to cool the walls of said mold, means forming slots extending outwardly from the interior surfaces of said mold cavity partially through the mold walls to relieve thermal operational stresses in the said mold walls, and metal inserts of greater ductility than the face material of the mold positioned in said slots, said inserts being substantially flush with the inner surface of said mold walls when at operational temperature.

2. A continuous casting mold according to claim **1** wherein said inserts are formed of high purity silver.

3. A continuous casting mold according to claim **1** wherein said ductile metal inserts are installed with a curved surface adjacent the inner surface of said mold wall.

4. A continuous casting mold according to claim **1** wherein some of said ductile metal strips extend parallel to the axis of said mold cavity throughout the length of said mold and some of said strips extend normal to the axis of and around the periphery of said mold cavity.

5. A continuous casting mold according to claim **1** wherein said inserts are formed of metal selected from the group consisting of gold, platinum, silver and their alloys.

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