MACHINE FOR THE CONTINUOUS CASTING OF SLABS BETWEEN BANDS

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ABSTRACT OF THE DISCLOSURE

The continuous casting of slabs in a belt-type mold provides for pressing of the belt against the solidified casting to preclude the occurrence of shrink spaces. The pressure is exerted elastically by mechanical means, such as backup rolls united in two endless circulating chains.

The invention relates to the continuous casting of metal slabs, namely of metal plates with a materially larger width than thickness. More particularly, the invention relates to the continuous casting of slabs, particularly of nonferrous metal slabs, with the aid of a belt-type mold. Still more particularly, the invention relates to the casting with belt-type molds, and to the molds themselves, which molds are characterized by the provision of two endless metal belts, preferably steel belts, that define between two opposite belt portions a mold cavity, and on the sides of which there are provided confining means such as two endless chains each composed of metal links, for instance steel links, or two steel bands, which move in synchronism with the cavity and form the side walls of the cavity.

The continuous casting of metal slabs with the aid of belt-type molds has been carried out before, reference being had to French Patent No. 1,314,592 and to a lecture given on Feb. 26, 1964, by R. W. Hazelett and C. E. Swartz before the Institute of Mining, Metallurgy and Petroleum Engineers, published by the Hazelett Strip-Casting Corporation.

Present belt-type molds for the casting of metal slabs, however, are deficient in that the two opposite portions of the endless belts that define the cavity are held apart for a fixed distance. This is a drawback because the casting will shrink in the cavity, and there will develop a wide shrink space between at least one of the wide surfaces of the casting and at least one of the belts, at most times the upper belt of the more or less horizontal mold cavity. The occurrence of this shrink space, on the other hand, is detrimental to the heat removal from the casting.

The lowering of the heat removal qualities may be compensated for by an energetic cooling of the steel belts, and is therefore in practice not very detrimental for the casting of slabs made of pure aluminum or pure zinc.

The casting, moreover, will not only shrink with its wide surfaces from one or both belts, but also at the sides resulting in lateral shrink spaces. These lateral shrink spaces are generally larger than the above-mentioned wide shrink spaces. Yet, even these lateral shrink spaces have not been given to bad castings made of pure aluminum or pure zinc.

The shrink spaces at the wide surfaces, however, are detrimental to castings of alloys which tend to sweat during solidification like, for instance, aluminum magnesium alloys with one (1%) percent of magnesium or more, and AlZnMg alloys. The sweating is particularly disturbing where, as usual, the surfaces of the casting are neither milled nor planed prior to the subsequent rolling: in modern plants, the endless casting slab that emerges from the belt-type mold is first passed through a control and regulating station and then directly into a hot rolling mill that runs in synchronism with the belt-type molds.

It is accordingly among the principal objects of the invention to provide means for continuously casting slabs which avoid the aforesaid disadvantages of the prior art.

It is another object of the invention to provide means for the continuous casting with a belt-type mold free from shrink spaces at least between one of the two wide casting surfaces and the belt adjacent thereto.

It is a further object of the invention to subject the portions of the opposite belts that define therebetween the mold cavity to pressures sufficient to avoid the occurrence of any shrink spaces between either belt portion and the casting.

It is still a further object of the invention to provide lateral bands made of metal, to complete the mold cavity. It is still another object of the invention to provide lateral bands of this type which are made of an elastic metal wire fabric.

It is still a further object of the invention to provide hydraulic, mechanical or pneumatic pressure means for pressurizing the casting in the mold cavity.

It is another object of the invention to provide for varying of the cooling intensity as the casting proceeds through the mold.

Further objects and advantages of the invention will be set forth in part in the following specification and in part will be obvious therefrom without being specifically referred to, the same being realized and attained as pointed out in the claims hereof.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. 1 is a symmetrical, vertical, sectional view of a belt-type mold in accordance with the prior art;
FIG. 2 is a large scale vertical sectional view of a belt-type casting mold in accordance with an embodiment of the instant invention;
FIG. 3 is a sectional view, taken on the line 3—3 of FIG. 2;
FIG. 4 is a large scale vertical sectional view of a nozzle in accordance with a modification; and
FIG. 5 is a sectional view similar to FIG. 5 but embodying a modification.

In FIG. 1 there is shown a belt-type mold of the prior art. The upper belt 10 has a portion which forms with a portion of a lower belt 11 a mold cavity 19. The mold cavity 19 is laterally confined by lateral confining means such as two chains 12, only one of which is shown in FIG. 1. The belts 10 and 11 are made of steel and may be provided on the exterior side with a lining, for instance of fibrous aluminum silicate, or graphite, bonded by plastic material. The chains 12 circulate non-circularly in opposite directions, so that the aforesaid lateral cavity confining parts thereof move in synchronism, from left to right in FIG. 1, throughout the length of the mold cavity 19 with the cavity forming portions of the belts 10 and 11.

Guiding rolls 14 are provided for the belts, and the guiding rolls are mounted on fixed supports 13. Conduits 15 and 16 are provided for conducting cooling water to the belts 10, 11 and for spraying the water thereonto throughout the width of the belts. A tundish 17 for the molten metal is provided that has a nozzle 18 through which the molten metal is supplied to the mold cavity 19.

On the opposite (the left, FIG. 1) side of the mold, the casting emerges as a solidified slab, namely a wide plate (not shown). Slabs have been cast with this belt-type mold of the prior art having a width of from .7 m.
Each roll 33 may be elastically journalled in two opposite bearings 36 of the respective chain link. The bearings 36 are movable and are actuated by pistons 37 of air pressure cylinders 38. The compressed air is brought to the cylinders 38 through conduits 39. Other form media, however, be used instead, for instance springs or the like, to press the pressure rolls 33 against the wide surfaces of the slab 32. Such an alternate arrangement is shown in FIG. 5 wherein spring means such as compression springs 49 form the pressure means to press the rolls 33 towards the casting 32.

As best shown in FIGS. 2 and 3, the moving belts 20 and 21 will be cooled throughout the portions 20' and 21' by spraying with a coolant, such as water. The water is conducted through conduits (not shown) to nozzles 40 that eject the water in flat sprays. In FIG. 3, the vertical hand-drawn lines 41 indicate the sprayed cooling water.

Means are arranged, indicated at 42, for sucking away the water vapor, and means 43 are arranged to suck away not only the water vapor but also the water.

The endless chains 34 and 34a circle in an opposite direction as the respective surrounding belts 20 and 21, respectively. Thus, while the belt 20 is indicated as circulating counterclockwise in the direction A, the chain 34 surrounded by the belt 20 circulates in the clockwise direction A'. Similarly, the belt 21 that moves clockwise as indicated at B, surrounds the endless chain 34a which moves counterclockwise as indicated at B'.

Instead of pressing the portions 20' and 21', respectively, towards the wide surfaces of the slab 32 by means of the aforesaid pressure rolls 33 and chains 34 and 34a, the portions 20' and 21' may be pressed towards the slab 32 by fluid streams which strike the portions 20' and 21' at high speed. Such fluids may be liquid or gaseous fluids. Of liquid fluids, such as water, large amounts are required for spraying requiring, in turn, removal conduits of large diameter. The use of pressurized gaseous fluid may therefore be preferable for this purpose.

The instant invention includes the use of pressurized gas jet nozzles which produce a cushion or pressurized gas of the type used in connection with vehicles of the type known as "Aerofill" or "Hydrofill" vehicles. A nozzle of this type is shown at 44 in FIG. 4. The nozzle 44 is drawn inwardly at 45. The pressurized gas, usually air, is supplied to the nozzle 44 at the inlet 46, and is caused by a body 47 to be displaced first outwardly and thence inwardly, as indicated by the arrow C, and finally leaves the nozzle 44 concentrically through an outlet 48, escaping sidewardly below the nozzle 44.

By this guiding of the compressed air, there is formed a pressurized air cushion between the nozzle 44 and its belt, for instance, the belt portion 20' of the belt 20, as shown in FIG. 4; and the air will press the belt portion 20' powerfully towards the slab 32.

In accordance with a further embodiment of the invention, the compressed air may be used not only to exert pressure on the belt 20, but also to cool it. For this purpose, water mist may be added to the compressed air for the combined pressurizing and cooling.

In accordance with the invention, the lateral walls of the mold cavity must be so arranged that they render possible the pressing of the circulating belts 20 and 21 along the portions 20' and 21', respectively, towards the wide surfaces of the slab 32. For this purpose, the instant invention provides for using, instead of the chains 32 of the prior art shown in FIG. 1, lateral confining means, such as lateral endless moving belts, that is, a panel of elastically compressible metal wire fabric that may be cooled by cooling air directed against the sides thereof.

In accordance with a preferred embodiment, these lateral bands preferably have a width which is considerably larger than the thickness of the slab 32, and which are pressed elastically throughout the length of the mold cavity 28 against the edges of the belts 20 and 21. This elastic pressing of the lateral bands towards the edges
of the belts 20, 21 is of particular importance, as it is hardy possible to guide the edges of the belts 20 and 21 accurately parallel. These edges are subject to continuous deviation towards the side of the other and, these deviations must be taken up by the elastic pressing of the moving endless lateral bands therewith. These lateral bands 22 will move throughout the portions 20' and 21' in synchronism and in the same direction D therewith. These lateral bands 22 preferably are made of metal and, in accordance with the preferred embodiment as previously stated, are composed of an elastic metal wire fabric.

For pressing these lateral bands 22 towards the edges of the belts 20 and 21, either pneumatic, hydraulic or mechanical means of well-known suitable construction may be used.

Regarding the cooling of the casting, the compressed air that is used for pressing the belts 20, 21 towards the slab 32 may suffice for the cooling of the slab 32 if the casting operation is carried out sufficiently slowly; for instance, for the casting of an aluminum plate having a thickness of 13 mm, the normal casting speed is from 5 to 10 mm per minute, heavier plates would, of course, need to be cast at a slower speed.

Where a more vigorous cooling is desired, there may, as previously mentioned, be added water mist to the compressed air. The cooling effect of this mixture is greater that of air alone, as more calories are necessary to evaporate water than to heat it from room temperature to an elevated temperature of, for instance, 60°C to 90°C. If desired, cooling water may be supplied in connection with the other steps of the instant method.

The operation in accordance with the invention is as follows:

Liquid metal enters into the tundish 26 through the tube 25 by way of the floating regulator 29. The molten metal is then discharged into the mold cavity 28 that is defined by the belt portions 20' and 21' and by the lateral confining means, namely the lateral belts 22 (FIG. 3).

The molten metal enters the cavity 28 in a liquid state, as shown at 31 in FIG. 2. Soon thereafter as the metal progresses in the direction D, as urged by the belts 20 and 21 that circulate in opposite directions A and B, the metal will solidify and will form the solid slab 32.

Solidification takes place in pure aluminum at between 650°C and 661°C and in an aluminum magnesium alloy with 3% Mg at between 650°C and 610°C.

After the solidification, the slab 32 continues to cool until it leaves the mold cavity 28. During its progress through the mold cavity 28, the slab 32 is subjected to pressure applied to its wide surfaces, as shown in FIG. 2 from above and below. This pressure may be exerted either by the pressure rollers 33 that are journaled by links of the chains 34 and 34a, which chains circulate oppositely relative to the encircling belts; or the pressure may be exerted by a pressure fluid, such as compressed air.

The purpose of this pressure application is to prevent the occurrence of shrink spaces between either portion 20', 21' and either wide surface of the slab 32 in the mold cavity 28.

As previously mentioned and as set out in detail below, the slab 32, during its movement in the direction D through the cavity 28, will be subjected to a cooling action. As previously indicated, where it is desired to cool the slab through a regulating station and thence directly into a synchronized hot rolling mill, it is important that the slab, after having become solidified, avoids the excessive loss of heat.

The distance between the casting machine and the hot rolling mill is usually about 10 m, and the temperature of the slab decreases throughout the distance for about 100°C. Thus, where the slab used is aluminum that emerges from the casting machine having a temperature of 450°C, it will upon arriving at the hot rolling mill have a temperature which is below the most propitious hot rolling temperature.

The invention provides that the cooling of the slab 32 inside the cavity 28 be so regulated, either with the aid of the air nozzles 44, or with any other suitable conventional means, for instance water spray means, that the slab 32 will be cooled in a varying manner throughout its path, as follows:

The metal will be cooled most vigorously in that portion of the cavity 28 in which it undergoes solidification and less heat will be removed from the slab 32 throughout the remaining portion of the cavity 28 through which the slab passes in solidified form. The purpose of the latter is so as to deliver the slab to the hot rolling mill at a desirably high temperature, for instance, in the case of pure aluminum, so as to reach the hot rolling mill at a temperature of 500°C. It may be advantageous to subject that portion of the cavity 28 in which the metal is liquid to a less vigorous cooling.

The invention provides, in accordance with a preferred mode of operation, for the cooling of the belt portions 20' and 21' merely by compressed air throughout that portion of the cavity 28 in which the casting metal is liquid; for the vigorous cooling in the solidified portion of the cavity 28, for instance, with spray water and compressed air simultaneously, or through compressed air containing water mist; and for the cooling of only with the aid of compressed air, preferably without the admixture of any water mist, throughout the remaining portion of the cavity 28.

Where the cooling is carried out with compressed air, the compressed air is preferably ejected alternately firstly through conventional nozzles by ejecting the stream of air at right angles to the belt to be cooled, and secondly through compressed air cushion nozzles in the direction D of the flow of the casting. In order to calibrate properly the heat removal in accordance with the portion of the cavity 28 and the condition of the casting therein, namely in succession in liquid form, solidifying and solidified, the content of the water mist admixture in the compressed air may be varied.

The invention provides furthermore that the pressure exertion by the fluid stream can be alternated with the spraying with a coolant.

The supporting rolls 24 may preferably be elastically displaceable towards the casting.

We wish it to be understood that we do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

Having thus described the invention, what we claim as new and desire to be secured by Letters Patent is as follows:

1. A machine for continuously casting a metal slab, comprising a mold including two oppositely circulating belts having opposite portions defining therebetweenthe mold cavity, lateral confining means completing said mold cavity, the mold cavity along said belt portions having a width at least twenty times its thickness between said portions, and pressure means pressing at least one belt elastically in the direction of the thickness of said cavity said portions towards the casting in the mold cavity for preventing shrink spaces.

2. In a machine, as claimed in claim 1, said pressure means comprising a series of rolls applied to at least one of said belts near said portion thereof and exerting elastic pressure thereagainst for pressing said portion towards the casting in a direction at right angle to the casting direction.

3. In a machine, as claimed in claim 1, said lateral confining means comprising two lateral bands moving substantially in synchronism with said portions in the casting direction and being composed of elastically compressible metal wire fabric.

4. In a machine, as claimed in claim 1, said lateral confining means comprising two elastic bands moving substantially in synchronism with said portions in the cast-
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ing direction, each band being pressed elastically in the direction towards the edges of said opposite portions for resiliently sealing the mold casting on the sides.

5. In a machine, as claimed in claim 1, said pressure means including rolls applied to at least one of said belts near said portion thereof, movable bearing means suspending said rolls, and resilient means connected to said bearing means and pressing the said rolls elastically towards the casting in the mold cavity.

6. In a machine, as claimed in claim 5, said resilient means comprising at least one air pressure cylinder for each roll, a piston in said cylinder and being in driving connection with the bearing means of said roll, said piston being operable by air pressure for resiliently pressing said roll towards the casting.

7. In a machine, as claimed in claim 5, said resilient means comprising at least one spring in driving connection with the bearing means of said roll resiliently pressing said roll towards the casting.

8. A machine for continuously casting a metal slab, comprising a mold including two oppositely circulating belts having opposite portions defining therebetween the mold cavity, lateral confining means completing said mold cavity, the mold cavity along said belt portions having a width at least twenty times its thickness between said portions, and pressure means pressing in the direction of the thickness of said cavity said portions towards the casting in the mold cavity, said pressure means comprising a series of rolls applied to said belts near said portions thereof and exerting pressure thereagainst for pressing said portions towards the casting in a direction at right angle to the casting direction, and means for applying the roll pressure to the respective portions of both belts comprising two endless circulating chains each positioned eccentrically within the orbit described by a belt, each chain having a plurality of links journaling said rolls, and each chain during its circulation moving said rolls to and from their active pressure position adjacent the respective belt portion.

9. In a machine, as claimed in claim 8, each chain circulating in opposite direction relative to the circulating direction of its encircling belt.

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