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BREAK-OUT CONTROL APPARATUS AND METHOD

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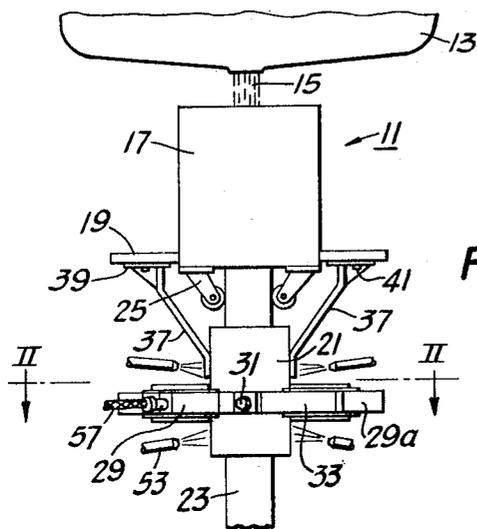


FIG. 1

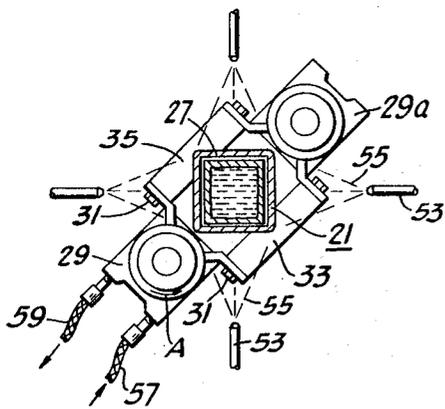


FIG. 2

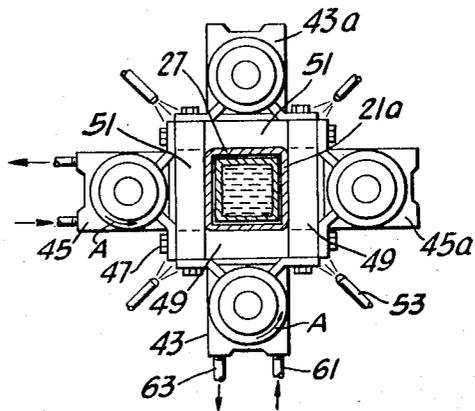


FIG. 3

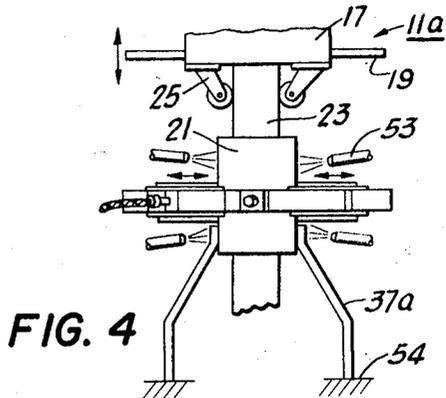


FIG. 4

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1

2

3,455,370
BREAK-OUT CONTROL APPARATUS AND METHOD

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ABSTRACT OF THE DISCLOSURE

In continuous metal casting, a sleeve surrounds the cast strand in the region of the spray chamber, just below the mold, and vibrates into and out of contact with the strand, which results in a reduction of surface irregularities, an enhancement of heat transfer from the strand, and strengthening of the skin of the strand.

This invention relates to continuous casting and, more particularly, to apparatus and method for controlling break-outs in the skin of continuously cast strands of metal.

While molten metal is being poured into a vertically oscillating continuous casting mold, the metal that contacts the chilled water-cooled walls of the mold "freezes," and a relatively thin skin forms around a molten metal core. Since "freezing" or solidification of the metal proceeds inwardly from the skin toward the center of the newly formed cast strand, the liquid metal core extends well below the bottom of the mold as the cast strand is continuously withdrawn from the mold.

Generally, a critical rate of withdrawal of a cast strand exists for any given cross sectional size of strand; exceeding this rate results in a skin so thin that the metallostatic head of molten metal causes the skin to warp, bulge, and even rupture in a "break-out," through which the molten metal of the core is spilled and lost. Therefore, the maximum rate of operation of a continuous casting machine is usually the rate at which "break-outs" of the casting shell or skin, in the region just below the mold, is not frequent enough to interfere with production.

The present invention discloses apparatus and method to control and prevent break-outs in the skin of a continuously cast strand. Such apparatus includes a sleeve that surrounds the cast strand, in a region of the spray chamber, just below the bottom of the mold, and that vibrates alternately into and out of contact with the billet at some preselected frequency. The vibration of the sleeve surfaces into and out of contact with the skin of the cast strand reduces surface irregularities, such as bulges, that signify a weakening and thinning of the skin of the strand. Further, the vibration enhances the rate of heat transfer from the molten metal core which results in a thickening, and strengthening of the skin of the cast billet, and an overall reduction in the frequency of break-outs.

For a further understanding of the present invention and for advantages and features thereof, reference may be made to the following description in conjunction with the accompanying drawing which shows for the purpose of exemplification a preferred embodiment of the invention.

In the drawing:

FIG. 1 is a schematic elevational view of a portion of a continuous casting machine incorporating an embodiment of the invention;

FIG. 2 is a sectional view along line II—II of FIG. 1;

FIG. 3 is a schematic plan view, similar to the view of FIG. 2, of another embodiment of the invention; and

FIG. 4 is a schematic elevational view of a portion of

a continuous casting machine incorporating another embodiment of the invention.

The portion of the continuous casting machine 11 shown in FIG. 1, includes a tundish 13 from which a stream of molten metal 15 flows into a conventional vertically oscillatable open-ended continuous casting mold 17. The mold 17 is provided with the usual horizontal mold table 19 from which is suspended a sleeve 21 that surrounds a portion of a continuous cast strand or billet 23, shown emerging from the bottom of the mold 17.

The mold 17 is provided also with a set of guide rollers 25 that are mounted to the bottom of the mold for the purpose of guiding the continuous cast billet 23 as it emerges from the casting mold.

The sleeve 21 is tubular and surrounds a portion of the length of the continuous strand 23 in a zone or region just below the bottom of the mold, and, more particularly, in a zone just below the guide rollers 25. The walls 27 of the sleeve 21 are spaced apart from the skin of the cast strand a short distance that is substantially equal to the stroke, or to the lateral movement of primary vibratory device 29 that is mounted to the sleeve (FIG. 1). The vibratory device 29 may be similar to a conventional vibrator, such as is marketed under the trademark Vibrolator by Martin Engineering Company, Neponset, Ill.

The vibratory device 29 is mounted by means of fasteners 31 to a pair of bars 33, 35, that are secured, as by brazing or welding, to the outer surface of the sleeve 21. A secondary vibratory device 29a is also mounted in the same manner to the rods 33, 35, but in opposed relation to the primary vibratory device 29. The vibratory devices 29, 29a, preferably, are positioned along a diagonal of the cast strand 23, about as shown in FIG. 2.

In one aspect of the invention, the assembly comprising the sleeve 21 and the vibratory devices 29, 29a is attached to and suspended from the mold table 19 by means of a plurality of elongate rods 37. The rods 37 may be secured to the sleeve 21 by welding, brazing, or the like, and each rod is provided with a sole plate 39 at its upper end, by means of which the rod is suitably secured to the mold table 19, as by bolts 41 or the like.

In another aspect of the invention, two groups of opposed pairs of vibratory units 43, 43a, and 45, 45a are arranged on the flat sides of a sleeve 21a that is similar to the other sleeve 21. In this embodiment of the invention, each pair of opposed vibratory units 43, 43a and 45, 45a are arranged in vertical spaced apart relation. Each pair of opposed vibratory units 43, 43a and 45, 45a is mounted, as by bolts 47, to bars 49, 51 that are secured to the flat wall surfaces of the sleeve 21a, in the manner that the bars 33, 35 (FIG. 2) are secured to the sleeve 21.

If preferred, of course, in some applications, only one pair of vibratory units may be arranged on a pair of opposed flat sides of the sleeve 21a.

In accordance with the usual practice, a plurality of cooling water spray nozzles 53 are so disposed below the bottom of the mold 17 that jets or sprays 55 of water, emerging from the nozzles 53, impinge on both the outer surface of the cast strand 23 and the walls of the sleeves 21 and 21a. The spray nozzles 53 are a part of the conventional spray cooling system, and the spray cooling water contacts the sleeves 21 and 21a so that cooling water flows down the outer walls and a film of cooling water also exists in the annular space between the sleeve and the cast strand. Such a film of water, in the annular space, increases the rate of heat transfer between the cast strand and the walls of the sleeves 21 and 21a.

In another aspect of the invention, the sleeve 21 of a continuous casting machine 11a may be independently supported, as shown in FIG. 4, on a suitable fixed structure 54 by means of elongate rods 37a that are similar to the rods 37. In this aspect of the invention, nozzles 53

are also disposed to direct sprays of cooling water onto the surface of the cast strand 23 and the sleeve 21.

In operation of the casting machine 11 (and machine 11a also), as soon as the cast strand 23 enters the sleeve 21, it is vibrated by flowing air at a controlled pressure through a hose conduit 57 into the primary vibratory unit 29. The air, flowing into the unit 29, propels a steel ball therewithin around a circular hardened ball race, generally in the direction of the arrow A (FIG. 2) and the air exhausts from the unit 29 through a hose conduit 59. The ball, rotating within the vibratory unit 29, sets up vibratory forces in the lateral plane of rotation of the ball that act normal to the walls of the sleeve 21 and normal to the surfaces of the cast strand 23. The sleeve 21, being attached firmly to the mold table 19, moves vertically in the same cyclical manner as the mold and also vibrates continually during the vertical movement cycle; one pair of adjacent sides of the sleeve 21 alternately impinging against the adjacent pair of sides of the cast strand 23 and the other pair of adjacent sides of the sleeve 21 alternately impinging against the other adjacent pair of sides of the cast strand 23.

In the primary vibratory units 29, 43, 45, the vibratory impact force on the shell of the cast strand 23 is controlled by regulating, in a known manner, the pressure of the air flowing in the primary vibratory units. In typical instances, using a UCV series Vibrolator, where the air pressure ranges from 20 to 100 pounds per square inch, the impact force of the unit against the sleeve would range from about 240 to 625 pounds. Typically, also, the number of vibrations or impacts per second would range from about 70 to 115. Hence, simply by regulating the pressure of air used to motivate the vibratory device, it is possible to obtain a wide range of impact forces and vibration impacts per unit of time.

While a particular type of vibratory unit, the Vibrolator, has been illustrated herein as an example, other suitable types of vibratory units may be employed if they are preferred. Such other types of vibratory units may be motivated electrically or by hydraulic fluid.

From the foregoing, several features and advantages of the present invention are apparent. The sleeve is slightly larger in size than the continuous cast strand it surrounds, and the sleeve is located along the length of the continuous cast strand in a zone where break-outs usually occur. The sleeve, moreover, is yieldingly mounted to vibrate and it repeatedly strikes the outer surface of the cast strand with a force that is readily controlled by regulating the pressure of the air flowing into the primary vibratory unit.

Since the entire sleeve is bathed in cooling water, a film of cooling water exists between the inner walls of the sleeve and the outer surface of the cast strand. And so, during the period of engagement of the sleeve with the cast strand the film of cooling water enhances the transfer of heat from the cast strand to the sleeve.

Each engagement of the sleeve with the skin of the cast strand smooths slight irregularities in the surface of the skin of the cast strand, thereby increasing the area of the sleeve that is in contact with the skin of the cast strand and the thickness of the skin.

At the incipience of a break-out, which is most likely to occur in the zone of the cast strand which is surrounded by the sleeves the vibratory walls of the sleeve impact the fluid molten metal, cool it during each period of contact, however brief, and change the fluid molten metal to "mushy" metal, which tends to solidify more quickly and close the break-out. The film of cooling water between the inner walls of the sleeve and the wall of the cast strand also enhances the cooling and the transformation of the molten metal to "mushy" metal.

A feature of the present invention is that the sleeve vibrates continually and impinges against the cast strand throughout the reciprocating cycle of the mold, in the instance where the sleeve is attached to the mold table.

Further, in the instance where the sleeve is independently mounted to a fixed support, the sleeve continually vibrates and impinges against the cast strand. Thus, at no time does the sleeve grip the cast strand; instead, the repetitive vibratory impinging against the cast strand effectively thickens the skin of the casting and reduces the tendency of the skin to break out. Any incipient bulging of the skin of the casting is smoothed and the repetitive impacting of the sleeve against the skin of the casting, in the zone where there is a tendency of a bulge to form, increases the thickness of the skin of the casting, and, thereby, reduces the chances of a break-out.

It should be readily apparent to those skilled in the art that the vertically spaced apart pairs of vibratory units 43, 43a, and 45, 45a may be separately motivated so that they will vibrate in several ways. They may vibrate together, in phase, or they may vibrate out of phase, in such a manner to approximate orbital movement of the sleeve.

It can readily be understood that if the frequency of the vibration is sufficiently high, a succession of blows will be struck against an incipient break-out area, with so brief a period between blows that inertia forces in the skin will be greater than the metallostatic forces acting to cause the break-out. Further, movement of the molten metal through the break-out area will be less likely to occur since the vibrating sleeve will force the molten metal back into the plane of the casting face, where the cooling action of the film of water and the sleeve will cause it to become "mushy" metal that solidifies more quickly and seals the break-out.

Although the invention has been described herein with a certain degree of particularity, it is understood that the present disclosure has been made only as an example and that various modifications and changes may be made within the scope of the invention as defined by the appended claims.

What is claimed is:

1. Apparatus for the continuous casting of metals including a vertically reciprocable mold from which a cast strand having a rectangular cross section is being continually withdrawn, wherein the improvement comprises:
 - (a) a sleeve surrounding in spaced apart relation a length of said cast strand at a location adjacent the discharge end of said mold; and
 - (b) means for cyclically impacting opposite sides of said sleeve against said strand whereby surface irregularities and the tendency for the strand surface to break out is reduced.
2. The invention of claim 1 wherein:
 - (a) said sleeve is yieldingly mounted to said mold and reciprocates simultaneously therewith.
3. The invention of claim 2 wherein:
 - (a) said means includes a vibratory unit mounted to said sleeve in such a manner that when said unit is actuated said sleeve vibrates transversely with respect to said strand and impacts said strand thereby reducing the tendency for the surface of said strand to break out.
4. The invention of claim 2 wherein:
 - (a) said means includes a pair of vibratory units oppositely mounted to said sleeve, each unit being of such a character that when both units are actuated said sleeve vibrates laterally relative to said strand and impacts said strand thereby reducing the tendency of the surface of said strand to break out.
5. The apparatus of claim 1 wherein:
 - (a) said means includes a first pair of vibratory units oppositely mounted to said sleeve and lying in a plane disposed transversely to the axis of said strand, and a second pair of vibratory units oppositely mounted to said sleeve and disposed in a second plane spaced apart from said first plane.
6. The method for continuous casting the metal wherein a vertical mold reciprocates and a cast strand having a

5

rectangular cross section formed therein is being continuously withdrawn from said mold, wherein the improvement comprises:

- (a) placing a sleeve in spaced apart relation around a portion of the length of said cast strand in a location below said mold; and
- (b) cyclically vibrating said sleeve into and out of surface contact with said strand whereby surface irregularities and break-outs in said strand are reduced.

7. The method of claim 6 including:

- (a) yieldingly mounting said sleeve to said mold whereby said sleeve reciprocates simultaneously with said mold.

8. The method for continuously casting a metal wherein a vertical mold reciprocates and a cast strand having a rectangular cross section formed therein is continuously withdrawn from said mold, wherein the improvement comprises:

- (a) placing a sleeve in spaced apart relation around a portion of the length of said cast strand in a location below said mold;
- (b) yieldingly mounting said sleeve to said mold whereby said sleeve reciprocates simultaneously with said mold; and
- (c) vibrating said sleeve laterally with respect to said strand whereby opposed surfaces of said strand alternately impact and disengage from said strand thereby reducing surface irregularities and the tendency for the surface of said strand to break out.

9. The method for continuous casting the metal wherein a vertical mold reciprocates and a cast strand having a rectangular cross section formed therein is continuously withdrawn from said mold, wherein the improvement comprises:

- (a) cyclically impacting the surface of said strand in a region below said mold whereby surface irregular-

6

ities and the tendency for the surface of said strand to produce a break-out are reduced.

10. The method for continuous casting the metal wherein a vertical mold reciprocates and a cast strand having a rectangular cross section formed therein is being continuously withdrawn from said mold, wherein the improvement comprises:

- (a) mounting a first pair of vibratory units in opposed relation to said sleeve, said first pair of units lying in a plane transverse the longitudinal axis of said strand;
- (b) mounting a second pair of vibratory units in opposed relation to the surface of said strand, said second pair of units being disposed in a second plane that is spaced apart from said first plane and is disposed transverse to the longitudinal axis of said strand; and
- (c) actuating said units whereby said sleeve vibrates laterally relative to said strand and impacts the surface of said strand to reduce the tendency for the surface of said strand to produce break-outs.

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