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APPARATUS FOR THE CONTINUOUS CASTING OF METALS

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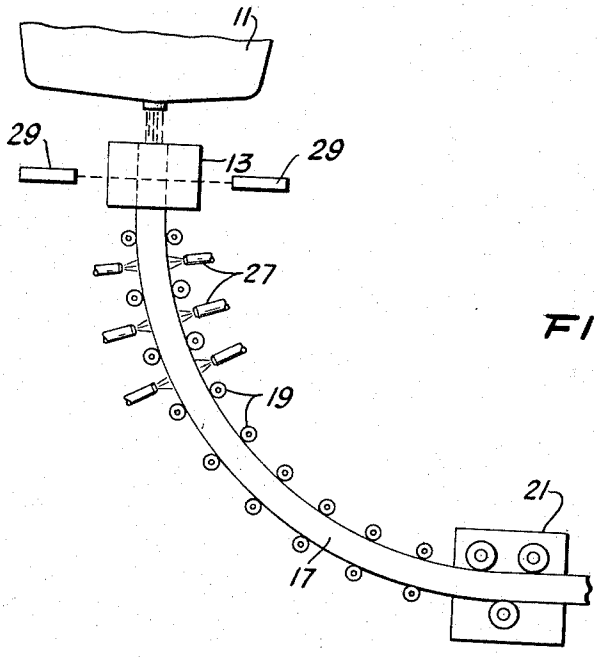


FIG. 1

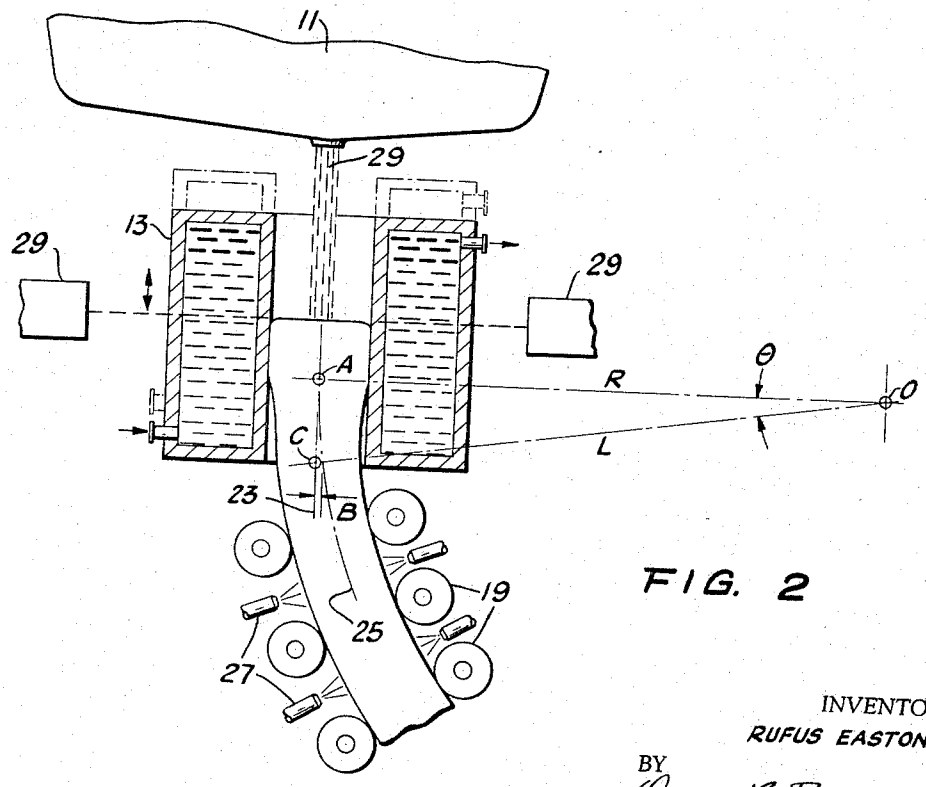


FIG. 2

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APPARATUS FOR THE CONTINUOUS CASTING OF METALS

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The present invention relates to continuous metal casting and, more particularly, to improvements in the method an apparatus for continuous casting of steel.

The continuous casting of metals, and steel in particular, is most readily accomplished when the axis of the casting mold is vertical, since the molten metal flows naturally downward from a ladle and tundish positioned above the mold. Vertical castings which are produced in this manner require an expensive, massive, high structure that is unsatisfactory for several obvious reasons. To overcome some of the objections to vertical casting machines, the billet has been forcibly bent, immediately it was formed, toward the horizontal and then straightened to bring it into a horizontal position.

It is more convenient to cut the strand into billets and handle them when they are disposed in a substantially horizontal position, but experience shows that forcibly bending continuously cast metal strands, especially while their central portions are still molten, causes cracks to form in the solid portions of the casting which are approaching complete solidification, but which have little or no tensile strength.

To overcome the tendency of the newly formed cast metal strand to crack, apparatus which provides an increased vertical distance between the mold and the strand-bending apparatus has been proposed for the purpose allowing the casting to solidify more completely before bending. But, such apparatus also requires elaborate support structure, which is expensive and occupies considerable space. Other apparatus has been suggested that includes a curved casting mold and an arcuate apron structure beneath it, on which the cast metal strand is supported. The curved mold, in such apparatus, is generally oscillated along the arcuate axis of the mold in order to prevent the casting from sticking in the mold. But, the mold oscillation mechanism in this form of apparatus is complicated and expensive. Additional apparatus has been proposed which employs a vertical mold which is relatively deep and which is positioned above a curved strand supporting apron. However, in such apparatus, the strand tends to solidify while it is still in the straight, relatively deep mold, and after it emerges from the mold, the rolls bend the strand. This causes the strand to develop flaws and defects.

In the present invention molten metal is poured into a vertically oscillatable mold, having vertical planar inner walls, and the cast metal strand, which is drawn therefrom, is supported upon an arcuate roller apron structure disposed beneath the mold. The central axis of the apron structure is laterally displaced toward one wall of the mold a distance substantially equal to the amount the casting shrinks from the respective wall of the mold; the shrinkage distance being measured at the bottom level of the mold in its lowest reciprocatory position.

For a further understanding of the present invention, and for features and advantages thereof, reference may be made to the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic view of a portion of a continuous casting machine wherein a cast metal strand is being formed; and

FIG. 2 is a schematic view illustrating a preferred embodiment of the present invention.

Referring to FIG. 1, the lower portion of a typical tundish **11** is illustrated in one operative position above a vertically oscillatable metal casting mold **13**. Beneath the casting mold **13**, there is provided an arcuate roller apron structure **15**, which may be of any conventional type, and which is capable of supporting a cast metal strand **17**, about as shown in the drawing. Such an apron structure usually includes a plurality of oppositely disposed rollers **19**, which are conveniently spaced apart a distance sufficient to admit the cast metal strand **17**. As illustrated schematically in FIG. 2, the casting mold **13** may be oscillated vertically in any suitable manner to prevent the strand **17** from sticking in the mold.

The cast strand **17** is received by a conventional straightener apparatus **21** which is fixed in a lower level position relative to the mold **13** so that the strand **17** forms an arc, preferably a quadrant, of a circle.

FIG. 2 illustrates schematically the casting mold **13**, the arcuate apron structure **15**, and a preferred level of the molten metal relative to the bottom of the casting mold. In a preferred embodiment of the present invention, the depth of the casting mold, is more than about six inches and preferably is about ten inches. It will be recognized that the depth of this mold is relatively shallow when compared to the usual conventional straight casting molds having a depth of about twenty-four inches.

The casting mold **13** is established with its axis **23** in a vertical position and the apron structure is established with its curvilinear axis **25** lying in the plane of the axis **23**. The curvilinear axis **25** is also tangent to the vertical axis at a point A which is at the level in the mold **13** where the cast metal first begins to shrink away from the walls of the mold. The point A also designates one terminus of a horizontal radius of curvature, R, of the axis **25** of the apron structure **15**.

It should be understood that, as the strand cools, it shrinks from the mold wall and below the level at point A, there is a gap between the casting and the wall of the mold. After the strand **17** leaves the mold it is received by the arcuate roller apron **15** in such a manner that the gap on the side nearest the center of curvature is reduced practically to zero. That is to say, the casting **17** almost touches the corner of the mold **13** when it is in its lowest reciprocating position.

Now, if the angle betwen the radius R and the secant line L is designated θ, then the axis **25** is displaced horizontally (toward the right in FIG. 2) a distance B which may be found by the relation:

$$B=R(1-\text{Cos }\theta)$$

and, the height of the point A, above the bottom of the mold designated as Ac in FIG. 2, is found from the relation:

$$Ac=R \text{ Sin } \theta$$

It is also known that the distance the point A is below the level of the molten metal in the mold is generally about 2–3 inches. Thus, it is evident that the total depth of metal in the mold is found by adding to the distance Ac, a distance between 2 and 3 inches.

For a further understanding of the present invention, assume, for example, that the radius of curvature of the apron axis, R, is equal to 180 inches and also assume that for a 4 inch square billet **17**, the shrinkage on each side, at the bottom level of the mold, is equal to 0.015. Thus,

the distance B is substantially equal to 0.015. The angle θ may now be found from the relation:

$$\theta = \mathrm{Cos}^{-1}\left(1 - \frac{0.015}{180}\right)$$

or

$$\theta = 0.74°, \text{ approximately}$$

Then, the distance Ac is found to be:

$$Ac = 180 \times \mathrm{Sin}\ 0.74°$$

or

$$Ac = 2.32 \text{ inches, about}$$

Hence the total depth of metal in the mold is between about 4.32 and 5.32 inches.

In a preferred embodiment of the invention, the vertically oriented casting mold **13** should have a depth not less than six inches, and, preferably, an overall depth of 10 inches. Molten metal flows from the tundish **11** into the mold **13** and the cast strand **17** is formed in the usual manner, using a dummy bar or other suitable device. The mold **13** may be reciprocated vertically to prevent sticking of the casting to the mold walls, and, as soon as the casting has formed, the casting may be continuously withdrawn, in the usual manner. Once the casting has started to form, and while it is being continuously withdrawn, the flow of molten metal may be regulated, using a suitable conventional metal-level-detecting device **29** (FIGS. 1, 2), to maintain the level of molten metal in the mold at a depth, which is about 4 or 5 inches above the bottom of the mold. Thereafter, throughout the pouring and casting process, the level of molten metal should be maintained within the range of 4 to 5 inches above the bottom of the mold.

When the casting **17** emerges from the mold of the present invention, it emerges following the arcuate motion imparted by the arcuate roller apron to the previously emerged portions of the casting, or to the starter bar used to commence the operation. As successive elements of the casting surface solidify in the mold, each will solidify in a slightly angular relationship to the immediately preceding solidified surface element because of this arcuate motion, so that the sum of a series of solidified surface elements will have an arcuate shape of radius corresponding to the roller apron. As each surface element has solidified in this desired relationship to the previously solidified portions of the casting, no appreciable mechanical forces and no bending are involved in the production of the arcuate casting.

The apron structure is generally provided with a plurality of spray nozzles **27**, in the usual manner, to prevent the heat of the molten metal within the casting from remelting the skin and destroying the casting. The casting is supported upon the apron structure which discharges the casting, after passing through the straightener apparatus **21**, in a substantially horizontal direction. Castings which are produced in accordance with the present invention do not exhibit the defects and flaws found in castings which are forcibly bent and then straightened.

In accordance with the present invention the depth of the mold should not be more than six inches. This depth is considerably less than the depth of molds used at the present time. Also, there will be no bending forces exerted on the casting that would cause defects and flaws, because the casting surface has solidified in the desired shape to conform to the arcuate apron structure without bending. Consequently the casting apparatus of the present invention has considerably lower height than machines used at the present time. Furthermore, the casting apparatus of the present invention is less expensive and more efficient than prior art devices.

I claim:

1. Apparatus for casting a continuous strand of metal using a vertical straight mold comprising:

(a) means for pouring molten metal into said mold and for vertically reciprocating said mold;

(b) means for maintaining the level of molten metal in the mold at a depth not over six inches from the bottom of the mold; and

(c) arcuate strand supporting and guiding means disposed beneath the mold having an arcuate axis tangent to the vertical axis of the mold at substantially the level in the mold where the casting commences to shrink away from the walls of the mold.

2. Apparatus for casting a continuous strand of metal using a vertical straight mold, comprising the steps of:

(a) means for pouring molten metal into said mold and for reciprocating said mold;

(b) means for maintaining the level of molten metal in the mold at a depth not over six inches from the bottom of the mold;

(c) means for arcuately supporting the strand emerging from the mold such means having an arcuate axis tangent to the vertical axis of the mold at substantially the level in the mold where the casting commences to shrink away from the walls of the mold; and

(d) means for discharging the strand in a substantially horizontal direction.

3. Apparatus for casting a continuous strand of metal comprising:

(a) means for pouring molten metal into a reciprocable vertical straight mold;

(b) means for maintaining the level of molten metal in the mold at a depth not over six inches from the bottom of the mold; and

(c) means for guiding the continuous strand emerging from the mold towards a horizontal level in an arcuate path which is substantially tangent to the axis of the vertical mold at substantially the level in the mold where the casting commences to shrink away from the walls of the mold.

4. Apparatus for casting a continuous strand of metal comprising:

(a) means for pouring molten metal into a reciprocable vertical straight mold not more than six inches deep;

(b) means for maintaining the level of molten metal in the mold at a depth substantially equal to one-half the depth of the mold;

(c) means for supporting the strand emerging from the mold in an arcuate path substantially tangent to the axis of the vertical mold at substantially the level in the mold where the casting commences to shrink away from the walls of the mold; and

(d) means for arcuately guiding the strand toward a substantially horizontal level.

5. Apparatus for casting a continuous strand of metal using a vertically reciprocable straight mold comprising:

(a) means for pouring molten metal into said mold having a vertical axis; and

(b) arcuate strand supporting and guiding means disposed beneath said mold and having an arcuate axis lying substantially in the plane of said vertical axis, said arcuate axis being substantially tangent to said vertical axis at the level in said mold where the casting commences to shrink away from contact with the walls of said mold and said arcuate axis horizontally displaced toward one side of said mold a distance substantially equal to the shrinkage distance at the bottom level of said mold in its lowest reciprocating position.

6. Apparatus for casting a continuous strand of metal comprising:

(a) means for pouring molten metal into a straight reciprocable mold having a vertical axis; and

(b) arcuate strand supporting and guiding means disposed beneath said mold in such a manner that the arcuate axis of said arcuate supporting means lies substantially in the plane of said vertical axis and said arcuate axis being laterally displaced toward one mold wall a distance substantially equal to shrink-

age distance of said cast strand at the bottom level of said mold when in its lowest reciprocatory position and with the depth of the metal in said mold being at least equal to the product of the radius of curvature of said arcuate axis multiplied by the sine of the angle between a horizontal radius and a secant through the point on the vertical axis at the bottom level of said mold at its lowest reciprocatory position.

7. Apparatus for casting a continuous strand of metal comprising:

(a) a vertically reciprocable mold having a plurality of spaced parallel vertical planar surfaces forming a casting zone not more than six inches deep;

(b) means for maintaining the level of molten metal in the mold at a depth not over six inches from the bottom of the mold; and

(c) means for arcuately guiding the continuous strand emerging from the mold towards a horizontal level whereby there is substantially no clearance between the casting and one wall of the mold at the bottom level of the mold at its lowest oscillatory level.

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