APPARATUS FOR CONTINUOUS CASTING

Filed May 9, 1966

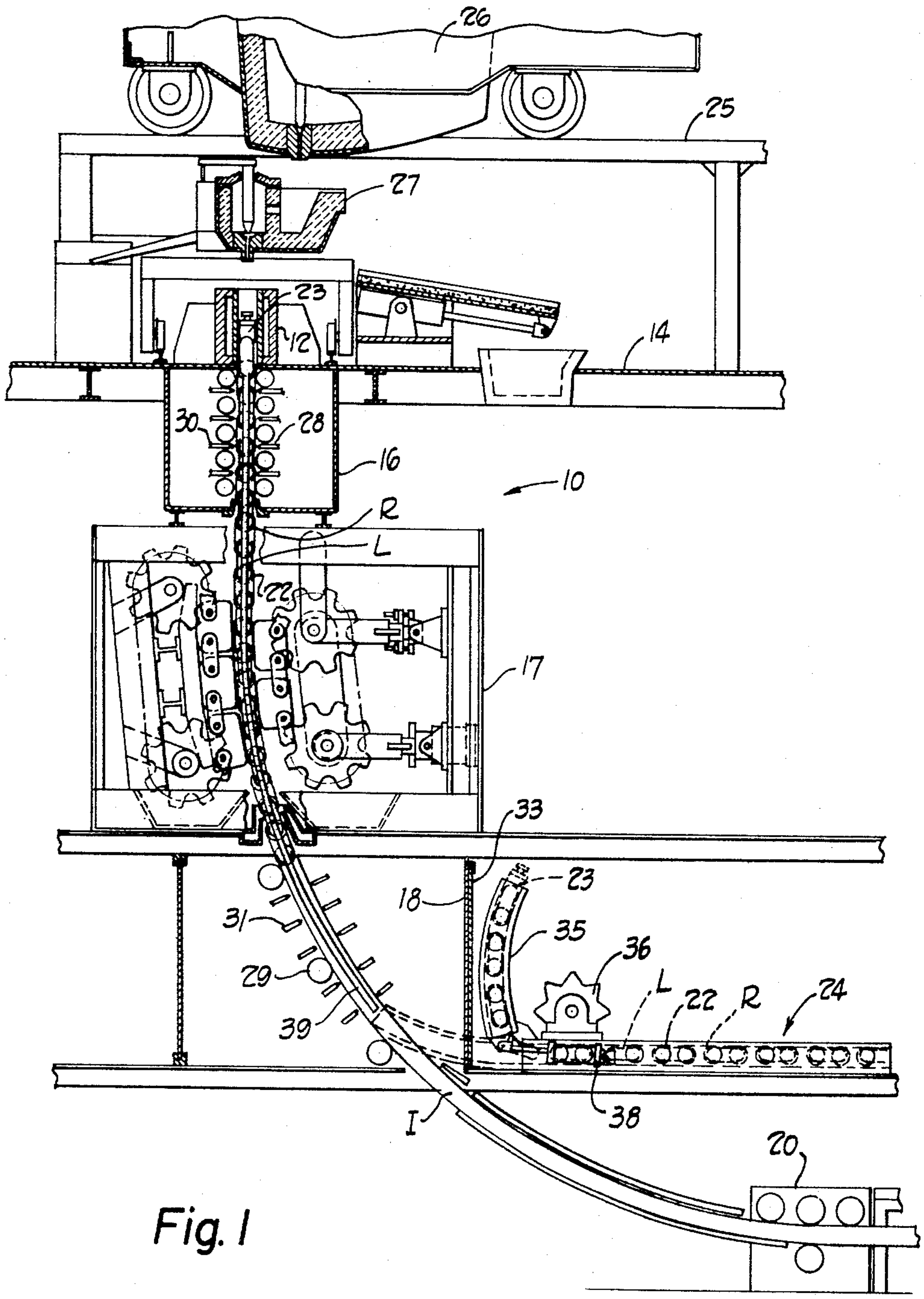

Fig. I

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May 27, 1969 A. MICHELSON 3,446,270
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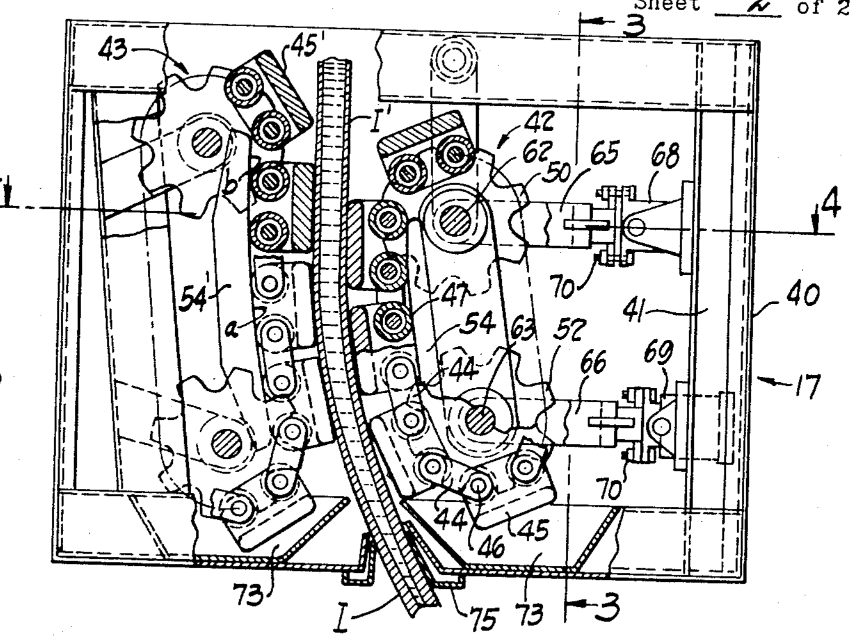

Fig. 2

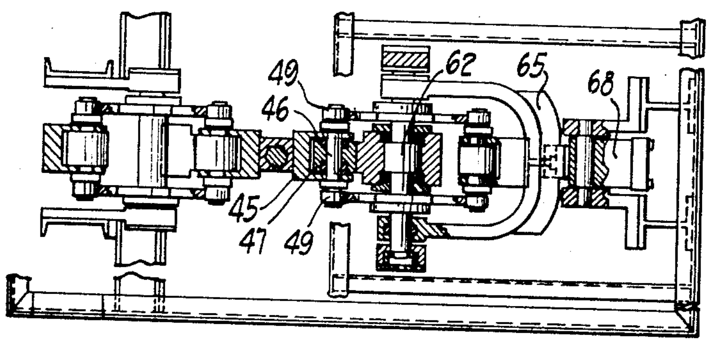

Fig. 4

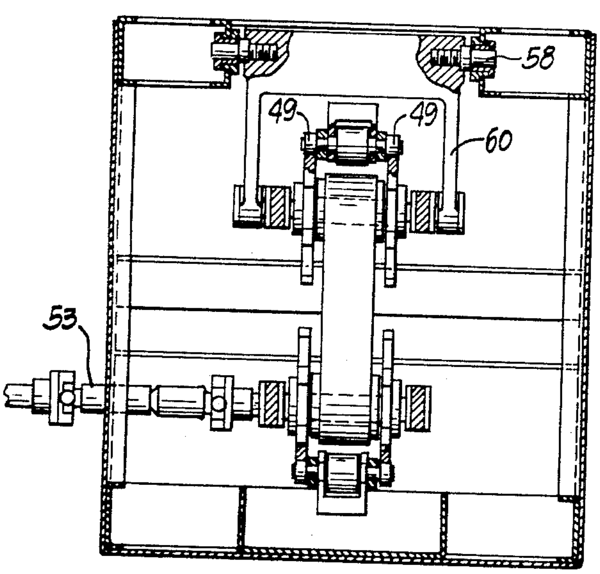

Fig. 3

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APPARATUS FOR CONTINUOUS CASTING

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U.S. Cl. 164—282 3 Claims

ABSTRACT OF THE DISCLOSURE

A continuous casting installation of the type including a generally downwardly directed flow-through mold from which an ingot is continuously cast. The disclosure provides guide means positioned subjacent the mold and including a pair of articulated link type guide means positioned in opposed ingot engaging relationship. The means are positioned to define a curvilinear path and include a plurality of curved ingot contact members which engage opposite sides of the ingot and guide it along the curvilinear path.

This invention pertains to the metal castings art and more particularly to the casting of continuous rounds, squares, ovals or slabs hereinafter referred to generally as ingots.

Casting is accomplished in a vertical, flow-through mold which may be either stationary or reciprocating and is usually water cooled. Inasmuch as the ingot emerges from the mold only partly solidified, it will normally have a liquid center of substantial depth contained within a solid outer skin. Therefore it is necessary for the mold to be located at a considerable height to allow for sufficient secondary cooling, usually in the form of a water spray, in order to complete the solidification process. To reduce the height of the casting plant, the ingot is customarily bent from the vertical casting position through an arc and subsequently straightened in a horizontal position before being cut into prescribed billet lengths. Nevertheless the pouring rate, size of the ingot, metallurgical properties of the metal and other factors influence the permissible rate of secondary cooling and to a large extent limit the reduction in height of the casing plant due to the fact that the ingot which has a deep liquid center must be allowed a longer vertical pass before complete solidification is reached and withdrawal and bending can commence.

Heretofore, withdrawal and bending of the ingot has taken place in a series of rolls located at or near the point of complete solidification. Attempts to decrease the casting height by moving the rolls closer to the mold have generally been unsuccessful primarily due to the fact that the huge withdrawal and bending forces then are applied to the still soft and weak skin of the ingot by the cylindrical rolls which have a very high contact pressure on a tiny strip-like area of the ingot skin often causing a rise in internal and surface cracks. This causing of defects in the ingot by a very high specific pressure of cylindrical withdrawal and bending rolls is a major problem arising from the application of such rolls in continuous casting machines.

Another problem arising from the bending and withdrawal rolls being placed at or below the point of complete solidification is that the straightening rolls must then be located at a point where the ingot is essentially below solidification temperature which necessitates increased straightening forces and causes higher stresses in the ingot which also can lead to surface cracks.

Moreover, the distance between the mold and the bending and withdrawal rolls determines the length of starting mechanism required. The starting mechanism is usually a long chain-like device with a bar on the end which is fed by the withdrawal rolls up into the mold at the beginning of a casting run and is used initially to provide a bottom in the mold and to withdraw the ingot. As a consequence of a larger starting mechanism, more expensive and heavier handling and storage equipment is required.

In overcoming these and other disadvantages of the prior art the present invention contemplates a method and apparatus employing a continuous application of a distributed withdrawal and bending force to a relatively large surface area of the ingot which permits commencing the withdrawal and bending closer to the mold where the ingot still has essentially a liquid core.

In accordance with the invention, a withdrawal and bending device travels continuously with the ingot and defines a curvilinear path through which the ingot is bent including a contacting member which occupies a relatively large surface area of the ingot relative to its cross sectional area so as to exert a rather low pressure on the partially solidified ingot.

Further in accordance with the invention, the bending and withdrawal device comprises at least two endless conveyors between which the ingot passes, each carrying a contacting member each of which has a common radius point.

In a further development of the invention, a method is provided of continuous casting which involves the steps of cooling the ingot as it emerges from the mold so as to develop a solidified skin of sufficient thickness to withstand a predetermined unit pressure and withdrawing the ingot from the mold and simultaneously bending it along a curvilinear path by the continuous application of a withdrawal and bending force moving with the ingot and applied over a relatively large surface area of the skin.

Further in accordance with the inventive method, secondary cooling of the ingot is carried out in two stages, the first stage including spray cooling between the mold and the application of the bending and withdrawal force of sufficient duration to develop an ingot skin of predetermined thickness and a second stage comprising spray cooling to complete solidification prior to the curved ingot being straightened.

In another aspect of the invention, because the starting mechanism must go through both straight and curved paths, it is made of a number of rolls whose diameter is equal to the minimum thickness of ingot to be cast.

The principal object of the invention is to reduced drastically a high specific pressure exerted on the ingot by prior art withdrawal, as well as bending rolls in order to avoid various defects on and under the ingot's surface caused by such pressure.

Another object of the invention is to reduce the overall height of the continuous casting plant and more particularly to permit the installation of continuous casting machines in existing plant facilities as a result of the reduction in casting height.

Another object of the invention is to start the application of ingot withdrawal and bending forces closer to the mold thereby substantially reducing the vertical cooling height.

Another object is to shorten the distance between the mold and the withdrawal and bending device which permits the use of a shorter starting mechanism with the further advantage of decreasing the size of the handling and storage equipment therefor.

Another object is the provision of a new and improved starting mechanism.

Still another object or advantage of the invention arising from the placement of the withdrawal and bending device closer to the mold is that the ingot is bent while its temperature is above or near the complete solidification point permitting the straightening mechanism to be moved closer to the mold at a spot where the ingot, though solidified, has a higher temperature thus decreasing the straightening forces and the consequent stresses developed in the ingot from this operation.

These and other objects will become apparent by referring to the following description and drawings wherein:

FIGURE 1 is a front elevational view of a casting machine employing a withdrawal and bending device constructed in accordance with the preferred embodiment of the invention;

FIGURE 2 is a partial view of the casting machine in FIGURE 1 showing the withdrawal and bending device in greater detail,

FIGURE 3 is a side elevational view of the withdrawal and bending device taken along line 3—3 of FIGURE 2; and

FIGURE 4 is a horizontal sectional view of the withdrawal and bending device taken along line 4—4 of FIGURE 2.

Referring now to the drawings wherein the figures are for the purpose of illustrating the preferred embodiment of the invention only and not for the purpose of limiting the same, in FIGURE 1 a casting machine **10** is shown generally including a flowthrough, water cooled mold **12** positioned on a pouring floor **14** and elevated above a cooling chamber **16**, a withdrawal and bending device **17**, a cooling chamber **18** and a roll straightener **20**. A starting mechanism **22** is shown, for purpose of illustration, in its two essential positions; firstly, with the bar **23** positioned in the mold **12** at the start of a run and; secondly, with the bar stored in the handling and storage equipment **24** after the ingot I is withdrawn and the machine **10** is operating on a continuous basis. The starting mechanism **22** comprises a number of rolls R having a diameter equal to the minimum thickness of ingot I to be cast which are connected together by at least two links L, one on each side, the width of which is less than the diameter of the rolls R. Continuous operation involves the shuttling back and forth on rails **25** of bottom pour ladles **26**, one of which is shown in pouring position over a tundish **27**. The flow of molten metal from the ladle **26** to the mold **12** is regulated in a known manner by the stopper of tundish **27** in accordance with a prescribed casting rate.

In accordance with the invention, the casting machine **10** is characterized by a two-stage secondary cooling arrangement in which the first stage is cooling chamber **16** and the second stage is primarily cooling chamber **18** but also may include spray cooling within the withdrawal and bending device **17**. Initial cooling is performed within the mold **12** by water circulation in the mold walls. The cooling arrangement is distinguished in that the chamber **16** is considerably reduced in size from the known prior art since, in the invention, the purpose of chamber **16** is not complete solidification of the ingot I, but only the formation of a crust or skin I′ (FIGURE 2) of sufficient thickness greater than that developed in the mold **12** to withstand the withdrawal and bending pressures of the device **17** as will be described more fully hereinafter. The first stage cooling chamber **16** is essentially similar to the second stage cooling chamber **18** in that each employs support rolls **28, 29** for guiding the ingot I. Water spray jets **30, 31** connected to a water circulatory system and heat exchanger (not shown) are interspersed between rolls **28, 29**. The cooling chamber **18** includes a sliding door **33** which seals an opening therein of sufficient size to accommodate the pivoted arm **35** of the starting chain storage and handling mechanism **24**. The length of the starting chain **22** is somewhat greater than the distance between the middle of the mold **12** and the middle of the withdrawal and bending device **17** or the distance between the withdrawal and bending device

17 and a drive spider **36**. During continuous casting, the arm **35** remains in the position shown in FIGURE 1 outside of the cooling chamber **18**. At the beginning of a casting run, however, the door **33** is opened and the arm **35** lowered to the dotted line position by means of an actuating cylinder **38**. The starting chain **22** is moved to and from the mold **12** by means of the spider **36** and the withdrawal and bending device **17** along longitudinal guides **39** positioned at each side of the ingot path.

Referring now to FIGURES 2–4, the withdrawal and bending device **17** is housed in a spray box **40** within which water jets (not shown) may be directed for cooling if necessary. In the preferred embodiment of the invention, a frame **41** supports a pair of endless conveyors **42, 43** on opposite sides of the ingot I, each being driven continuously with the ingot so that there is no relative movement. To the extent the conveyors **42, 43** contain essentially duplicate parts, those parts are identified by like numerals where applicable, however, to the extent conveyors **42, 43** differ but contain similar parts, like numerals will be used in identifying such parts with the addition of a prime mark with respect to conveyor **43**. Each conveyor **42, 43** is made up of a number of links **44** joined together by a plurality of contact members or pressure shoes **45, 45′** by means of connecting pins **46**, each carrying a roller **47** at the center and rollers **49** on the opposite ends. Upper and lower conveyor drives **50, 52** each have axially spaced sprocket elements which engage the pin roller **49** for driving the conveyors **42, 43**, each of which has a separate, but synchronized drive **53**. Conveyors **42, 43** each include a track section **54, 54′** upon which the central rollers **47** of each pressure shoe **45, 45′** ride. Track section **54** has a convex curvature and in cooperation with a concave portion *a* of track section **54′** defines a segment of a circle having a predetermined radius the length of which depends largely on the cross sectional area of the ingot I and the grade of steel being cast. Generally the length of radius R will be about 25 times the thickness of the ingot I. An upper portion *b* of track section **54′** which extends vertically above the top of track section **54** has a flat surface which serves to take the consequential bending forces as the ingot I enters the curved pathway. Therefore, the forces created in bending the ingot I are transmitted directly to the frame **40** so that the mechanism can be of lighter construction.

The track segment **54′** and upper and lower sprockets **50, 52** of conveyor **43** are fixed rigidly to the frame **40** while the track section **54** and sprockets **50, 52** of conveyor **42** are suspended on a hinge **58** and a bifurcated arm **60** which supports the upper sprocket shaft **62**. The upper end of the track section **54** is carried by the shaft **62** as shown in FIGURE 4 while the lower end is carried by the lower drive sprocket shaft **63** in a similar manner. Upper and lower bifurcated arms **65, 66** are also journaled on the upper and lower sprocket shafts **62, 63** and rest on restraining cylinders **68, 69** which establish the spacing between track sections **54, 54′** to develop the required withdrawal and bending forces applied by the shoes **45, 45′**. Should a change in ingot size be required, nuts **70** on cylinders **68, 69** may be adjusted so as to change the distance between pressure shoes **45, 45′** according to the thickness of the ingot to be cast. The pressure shoes **45, 45′** are curved, convexly and concavely respectively to match the curvature being developed in the ingot I as it passes between the track sections **54, 54′**. Since the pressure shoes **45, 45′** get hot during contact with the ingot, two cooling tanks **73** with flowing water are positioned so that the pressure shoes **45, 45′** pass through upon each revolution of the conveyors **42, 43**. Water spray box **40** includes a water seal **75** at the lower end where the ingot I emerges to collect cooling water.

As referred to previously, it occurs in the prior art that because the withdrawal and bending forces are transmitted to the ingot by cylindrical rolls, essentially a line contact is made with the ingot which is occasioned by extremely high pressures. This dictates that the placement of the withdrawal and bending rolls be at or near the point of complete solidification of the ingot with the consequent disadvantages discussed.

In accordance with the present invention, and particularly where the ingot has a deep liquid center as usually found in casing steel for example, the withdrawal and bending device **17** provides for continuous application of a distributed bending and withdrawal force to a relatively large surface area of the ingot which eliminates distortion and crack formations in the ingot and permits location of the mechanism closer to the mold at a point where the ingot is only partially solidified as shown in FIGURE 2. With the invention, it is necessary only that the ingot have a skin I′ of sufficient thickness to withstand the distributed forces. The distributed forces are applied to a surface area of the ingot which is essentially a function of its cross sectional area. That is, for ingots of considerably larger cross section, the conveyors **42, 43** will be considerably longer and the radius of curvature also considerably longer so that the bending forces are less concentrated. As a rule of thumb, the radius should be about 25 times the thickness of the ingot I.

Moreover, with the invention the shoes **45, 45′** applying the distributive withdrawal and bending forces move with the ingot while it is being deformed. This is distinguished from the prior art where the ingot is pulled through rolls inducing certain dynamic rolling stresses thereto.

Modifications of the invention may be visualized by persons skilled in the art, however it should be appreciated that such changes are intended to fall within the invention in its broadest aspects as defined in the appended claims except insofar as limited by the prior art.

I claim:

1. A continuous casting installation including a flow-through mold from which an ingot is cast and guide means for engaging opposed surfaces of the ingot and continuously moving therewith along a curvilinear path intercepting the initial direction of movement of the ingot from the mold and diverting it along said curvilinear path, said guide means including: a pair of opposed stationary track sections, one concave and the other convex; said track sections positioned directly opposite each other and defining said curvilinear path and between which the ingot passes; and adjustable frame means for restraining said track sections against movement from a predetermined spacing in relation to the ingot thickness so that the ingot is deflected from its original course while being withdrawn from the mold; endless conveyor means carried by each of said track sections, each conveyor means including a plurality of pivotally interconnected ingot engaging members having contact areas sufficiently large to distribute the ingot bending forces over an area larger than those obtainable with cylindrical roll contact; a pair of vertically spaced sprockets for each conveyor successively engageable with the ingot engaging members to move the conveyors around their respective track section; and drive means for driving each conveyor in synchronism with respect to the ingot withdrawal rate.

2. The invention as defined in claim **1** wherein the concave track section includes a flat portion extending upwardly a considerable distance above the top of the convex section for assuming consequential bending forces.

3. The invention as defined in claim **1** wherein the ingot engaging members have curved contact surfaces corresponding in curvature to the curvature of its respective track section.

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