ABSTRACT OF THE DISCLOSURE

A method and apparatus for continuously casting metal in ingot form in an arcuate channel having open ends.

This invention relates to machines for the production of continuous cast billets, blooms, slabs and other shapes, and particularly to rotary type continuous casting machines in which a set of arcuate mould half mould segments is closed in pairs over an arc of the machine to form a casting channel into which molten metal is poured.

There are various types of continuous casting machines in use. According to the arrangement of the mould they can be classified into machines with fixed or reciprocating solid moulds whose function is well known in the industry. (b) In machines with continuously moving moulds. The latter include the conveyor type machine, which have mould halves fastened to endless conveyor chains and moving around pairs of sprocket wheels. When the mould halves are brought together along the straight part of the conveyor they form one longitudinal mould cavity in which the liquid metal is being poured. Another type employs a grooved wheel, whose groove is closed on part of its circumference by a metal belt or by mould halves fastened to an endless chain which form a mould channel in the shape of a circular segment.

The machines with continuously moving moulds permit a continuous discharge of the solidified casting without the necessity for reciprocation, but they have the following difficulties in common: Synchronization of movement of the two elements which form the mould channel is difficult. Clearances in linkages, backlash in gears, etc. cause relative movement between the two mould halves which may tear the initially formed fragile skin of the casting thereby causing breakouts of liquid metal and surface defects. It is very difficult to provide efficient cooling in moving mould elements (mould halves) fastened to chains or traveling belts. As the chains stretch, the clearance between mould sections increases causing metal leakage.

Another disadvantage of existing machines with continuously moving moulds is that the cross sectional dimensions of the mould channel cannot be altered. Fixed or reciprocating solid moulds can be provided with a tapered mould aperture in order to make allowance for the fact that the solidifying casting contracts and the mould faces. This greatly reduces heat transfer from the casting to the mould and lowers the effectiveness of the mould despite its usually greater length than that of conventional casting machines.

If the casting clings to one face of the two mould halves and separates at the other face uneven cooling of the casting results with consequent tearing of the casting shell and/or distortion of the casting in the mould.

The present invention consists essentially of a wheel or rotor which rotates around a horizontal, tilted or vertical axis. Hinged to the hub of the rotor and extending radially on each side of the rotor, not unlike the spokes of an umbrella, are a series of levers, each of which carries a mould segment. The centre of the radius of each half mould segment is identical with the axis of the shaft of the rotor. The mould segments in their closed position form two parallel rings arranged on each side of the main plane of the rotor and touching each other along this plane. Each ring consists of a plurality of mould halves, and opposing mould halves can be opened or closed like the jaws of a pair of piers. The opening and closing operation is effected by circular cams, one located on each side of the rotor. A roller follower is mounted on each of the levers carrying the mould segments and engages with the circular cam on its side of the rotor. The closed mould segments forming the casting channel are fed with molten metal from a tundish located at the periphery of the machine adjacent that portion of the cam which effect closing of the mould segments to form the casting channel. The tundish is fed molten metal in the usual manner from a ladle.

The casting channel formed by the closed mould segments will usually be located approximately in a lower quarter segment of the machine generally defined as from a 2:30 o'clock position of a clock dial to a position at 6:00 o'clock on a clock dial. If useful the effective length of the mould channel could be extended by changing the circular cam.

A series of rollers located about an arc coincident with the sector of the casting channel, clamp the opposing mould segments together. These rollers can be adjusted in relation to the mould segments to permit the proper degree of clamping pressure and for expansion and contraction of the mould segments.

 Provision is made in the mould segments whereby the skin formed about the molten metal within the arcuate casting channel will have an excess of metal on the inner arcuate surface so that, when the curved casting is straightened out on leaving the machine, the excess of metal skin on the inner arcuate surface will straighten out and not rupture, thereby giving maximum protection to the still molten core of the casting.

Cooling water is fed to the mould segments on each side of the rotor through suitable ducts formed in the rotor and is discharged from the mould segments in similar manner.

The device hereinafter described and illustrated is rotatable in a vertical plane about a horizontal axis. However, it is understood that this is for illustrative purposes only. The device may be tilted at an angle to the horizontal or receive a continuous stream of molten metal at the point where the mould segments close, and eject a continuous casting at the point where the mould segments open.

A further object of the invention is to provide a continuous casting machine having pairs of mould segments located radially with respect to the axis of rotation of the machine, which automatically close and open at designated locations about the machine, and will automatically receive a continuous stream of molten metal at the point where the mould segments close, and eject a continuous casting at the point where the mould segments open.

A further object of the invention is to provide a continuous casting machine having means in the surface of the mould segments whereby, on straightening of the curved cast billet on leaving the ma-
chine, the surface of the casting enclosing the still fluid core, will not crack or rupture.

These and other objects of the invention will be apparent from the following detailed specification and the accompanying drawings, in which:

FIG. 1 is a side elevation of the rotary casting machine according to the present invention.

FIG. 2 is a vertical section taken on the line 2-2 of FIG. 1.

FIG. 3 is a partial vertical section taken on the line 3-3 of FIG. 2.

FIG. 4 is an enlarged partial side elevation showing the details of the mounting of the radial levers and mould segments and also showing the cooling water feed and discharge to the mould segments.

FIG. 5 is a vertical section taken on the line 5-5 of FIG. 4.

FIG. 6 is a vertical elevation of one half mould segment showing a modified form of mould cavity.

FIG. 7 is a perspective view of a section of ingot as formed by the modified mould segment shown in FIG. 6.

FIG. 8 is a diagram of a portion of a cast billet showing the accordian formation of the inside curved face of the casting which is straightened out when the casting is straightened on leaving the casting machine.

Referring to the drawings, the continuous rotary casting machine 5 is here shown as being rotatable in a vertical plane. The machine 5 consists of a pair of support frames 6 mounted in spaced apart relation on a base 7, each support frame 6 having a bearing 8 axially aligned horizontally with each other. A rotor 9 is journeled in the bearings 8 and rotates in a vertical plane between the frames 6.

The rotor 9 comprises a hub 10 and a rim 11 supported by a series of spokes 12 projecting radially outwards from the hub. A pair of axles 13 projecting from the hub 10 are journeled in the bearings 8. One of the axles 13 carries the drive sprocket wheel 14 which, in turn, is drivably connected with the drive shaft 15 by the chain link belt 16.

A pair of annular face plates 17 are mounted, one on either side of the spokes 12 and are supported rigidly thercon by the gussets 18 welded to the spokes 12 and face plates 17.

A series of radially disposed brackets 19 are secured in pairs opposite each other on the outward facing surfaces of the face plates 17 by the bolts 20. Radially disposed levers 21 are pivotally mounted, one on each bracket 19 by means of the pivot pins 22. Each of the levers 21 extend radially outwards beyond the rim 11 of the rotor 9, and the opposing faces 23 each support a half mould segment 24 and are secured thereto by the bolts 25.

The rim 11 of the rotor 9 is provided with a series of transverse slots 26 to receive the tongues or keys 27 on the lower surface of the half mould segments 24, preferably two on each half mould segment, for the purpose of accurately locating the opposing half mould segments 24 on the rim 11 in their exact peripheral position. That portion of the levers 21 extending beyond the rim 11 and the half mould segments 24 have their edges 28 coinciding with radiating lines passing through the axis of the rotor 9.

In the form of the invention illustrated there are shown twenty-four pairs of levers 21 and half mould segments 24, therefore, the edges 28 of the levers and half mould sections have an inclusive angle of 15 degrees. A greater or lesser number of levers and half mould segments could be used in which case the inclusive angle would be correspondingly different.

Mounted on suitable brackets 29 on the extension frame 30 are a pair of annular guide cams 31 located one on either side of the rotor 9 and spaced outwardly of the levers 21. These guide cams 31 are of channel section with the channel facing radially outwards. Mounted on each of the levers 21 is a bracket 32 each supporting a roller 33 adapted to rotate about an axis parallel with the plane of the levers 21.

The annular guide cams 31 in the sector 34 which is defined as from approximately 2:30 o'clock to 6:00 o'clock looking on the dial face of a clock, governs the closed positions of the mould segments 24. In this sector 34 the guide cam has the radial axis of its channel parallel to the plane of the rotor 9. A series of clamping rollers 35 journalled in bearings 36 mounted on the brackets 37 are disposed in an arc spaced radially outwards of the guide cam 31, bear against the outer ends of the levers 21 to hold the opposing half mould segments in their closed position to form the casting channel 38. Each roller 35 rotates about a radial axis and the brackets 37 and rollers 35 are adjustable normal to the plane of the rotor 9 by means of shims 39 or other suitable adjusting means.

At the position 2:30 o'clock and 6:00 o'clock looking on the face of a clock, the radial axis of the channel of the guide cams 31 are offset at 40 an angle of approximately 10 degrees to the plane of the rotor 9. This offset is effective over the sector 41 between 6:30 o'clock and 2:00 o'clock on the clock dial and defines the sector of the machine in which the opposing half mould segments 24 are held apart from each other. By offsetting the radial axis of the channel of the guide cam 31 the rollers 35 are forced to follow the channel and consequently the levers 21 and half mould segments 24 take up the position shown in the upper half of FIG. 2.

The opening between the half mould segments 24 approaching the position where the segments are forced by the cams 31 into the closed position, is sufficiently wide to accommodate the tundish 42. The outlet 43 of the tundish 42 is located immediately above the upper end of the mould channel 38 formed by the closed mould segments 24 immediately below. This outlet 43 may be in the form of a nozzle or refractory tube extending into the adjacent open end of the mould channel 38. Liquid metal is poured into the tundish 42 from a ladle 44.

Each half mould segment 24 is provided with a cooling water passage 45 with inlet and outlet connections 46 and 47 respectively. Cooling water is fed into the machine through the bore 48 in one axle 13 and into alternate hollow spokes 12a of the rotor 9, thence through arcuate conduits 49. Each conduit 49 has a series of outlets 50. Each adjacent half mould segment. A flexible connection 51 connects each outlet 50 with the inlet 46 of its adjacent half mould segment. Similarly, each cooling water outlet 47 in the half mould segments is connected with an inlet connection 52 in the arcuate conduit 53 by the flexible connections 54. The arcuate conduits 53 are connected to alternate hollow spokes 12b of the rotor 9 which, in turn, are connected with the bore 54 of the other of the axles 13. The end of the separate arcuate conduits 49-53 opposite from the hollow spokes to which they make connection are blanked off by the surface of the spoke, as will be seen by the direction arrows in FIG. 4.

The rate of cooling in the mould segments 24 when in their closed position can be varied in several zones as e.g. from say 2:30 to 3:30 o'clock, from 3:30 to 4:30 o'clock and from 4:30 to 6:00 o'clock, as viewed in FIG. 1. This variation of cooling while the mould segments are closed would have a definite metallurgical advantage.

Referring now particularly to FIGS. 6, 7 and 8. In the casting of a curved ingot which, after casting has to be straightened, the inside face of the curved ingot has to be stretched. This stretching would, normally, cause the skin surrounding the still partially molten metal casting to develop cracks or actually fracture. In order to overcome this, the inner curved portion of the mould cavity 55 in the half mould segment 24a is provided with a series of recesses 56 which taper off in depth radially outwards as seen in FIG. 6.
In FIG. 7 there is shown a section of ingot taken from the machine, partly curved and partly straightened. The curved portion 57 has a series of slightly raised portions 58 on its inner curved edge 59. These raised portions or corrugations 58 increase the surface area of the skin 60 which encloses the still molten core 61 of the ingot at the time any one portion of the ingot is about to be discharged from the machine. The straightened portion 62 of the ingot leaving the machine has its inner curved edge stretched, thereby straightening out the corrugations so that the skin 60 is not subjected to cracking or fracturing.

The sum of the developed lengths C of the corrugations is equivalent to the sum of the straightened lengths C, and the corrugations diminish towards the neutral axis of the ingot. During the straightening of the ingot the excess material provided by the raised portions 58 of the corrugations is flattened out as the fibers of the ingot on the inner curvature are being stretched. Any remaining slight corrugations will be rolled out in subsequent operations in the rolling mill.

The operation of the continuous casting machine above described is as follows: To start the cast, a dummy bar is first inserted into the mould channel 38 at the 2:30 o'clock position of the mould segments 24 and the guide cam 31 approach the 2:30 o'clock position and the adjacent offset portion 40 of the guide cam 31, they carry the half mould segments 24 into the mould closing position.

Pouring of the metal from the tundish 42 is then started, the metal being directed into the open mouth of the mould channel 38 against the dummy bar. Continuous rotation of the roller assembly brings the dummy bar and the ingot to the discharge portion of the machine which is approximately at the 6:30 o'clock position where the offset portion 40 of the guide cam 31 causes the rollers 33 and their associated levers 21 to pivot outwards away from the plane of the rotor 9 and carry with them the half mould segments 24. The curved ingot as it is discharged from the mould channel 38, is straightened out and carried away for further treatment, such as spray cooling, straightening and cutting in the conventional way. A pair of pinch rollers driven in synchronization with the casting discharge speed of the machine may be installed a distance away from the casting machine to assist in removing the castings.

The speed of rotation of the machine will be adjusted, as will be the rate of pouring of the metal from the tundish 42 into the mould channel 38, to ensure that the cast ingot will have a sufficiently high rate of solidification consistent with good skin characteristics. Good skin characteristics are a most important feature in the casting of steel where the ingot has a semi-liquid core for a period of time after discharge from the machine and the skin must be protected against rupture, particularly at the time the curved ingot is being straightened. The above described method of preventing rupture involving engaging the inner curved surface of the ingot to provide sufficient skin material for stretching, effectively prevents rupturing or thinning of the skin during the straightening operation.

The fact that the curved mould segments move at the same speed as the forming ingot means that there is no slippage between ingot and mould and that the corrugations are uniformly formed on the ingot by the mould and that the skin will form with a more or less uniform thickness which will have sufficient flexibility to stretch during the straightening of the ingot.

The design of the annular guide cams 31 combined with the adjustability of the clamping rollers 35 is such that the mould cavity can have a slightly greater width transversely of the plane of the rotor 9 at the entrance end of the mould channel 38 and that this transverse width will gradually be decreased towards the discharge end of the mould channel. This reduction in transverse width of the mould channel will effectively take care of the shrinkage of the cast ingot.

In FIG. 7 there is shown a section of ingot taken from the machine, partly curved and partly straightened. The curved portion 57 has a series of slightly raised portions 58 on its inner curved edge 59. These raised portions or corrugations 58 increase the surface area of the skin 60 which encloses the still molten core 61 of the ingot at the time any one portion of the ingot is about to be discharged from the machine. The straightened portion 62 of the ingot leaving the machine has its inner curved edge stretched, thereby straightening out the corrugations so that the skin 60 is not subjected to cracking or fracturing.

The sum of the developed lengths C of the corrugations is equivalent to the sum of the straightened lengths C, and the corrugations diminish towards the neutral axis of the ingot. During the straightening of the ingot the excess material provided by the raised portions 58 of the corrugations is flattened out as the fibers of the ingot on the inner curvature are being stretched. Any remaining slight corrugations will be rolled out in subsequent operations in the rolling mill.

The operation of the continuous casting machine above described is as follows: To start the cast, a dummy bar is first inserted into the mould channel 38 at the 2:30 o'clock position of the mould segments 24 and the guide cam 31 approach the 2:30 o'clock position and the adjacent offset portion 40 of the guide cam 31, they carry the half mould segments 24 into the mould closing position.

Pouring of the metal from the tundish 42 is then started, the metal being directed into the open mouth of the mould channel 38 against the dummy bar. Continuous rotation of the roller assembly brings the dummy bar and the ingot to the discharge portion of the machine which is approximately at the 6:30 o'clock position where the offset portion 40 of the guide cam 31 causes the rollers 33 and their associated levers 21 to pivot outwards away from the plane of the rotor 9 and carry with them the half mould segments 24. The curved ingot as it is discharged from the mould channel 38, is straightened out and carried away for further treatment, such as spray cooling, straightening and cutting in the conventional way. A pair of pinch rollers driven in synchronization with the casting discharge speed of the machine may be installed a distance away from the casting machine to assist in removing the castings.

The speed of rotation of the machine will be adjusted, as will be the rate of pouring of the metal from the tundish 42 into the mould channel 38, to ensure that the cast ingot will have a sufficiently high rate of solidification consistent with good skin characteristics. Good skin characteristics are a most important feature in the casting of steel where the ingot has a semi-liquid core for a period of time after discharge from the machine and the skin must be protected against rupture, particularly at the time the curved ingot is being straightened. The above described method of preventing rupture involving engaging the inner curved surface of the ingot to provide sufficient skin material for stretching, effectively prevents rupturing or thinning of the skin during the straightening operation.

The fact that the curved mould segments move at the same speed as the forming ingot means that there is no slippage between ingot and mould and that the corrugations are uniformly formed on the ingot by the mould and that the skin will form with a more or less uniform thickness which will have sufficient flexibility to stretch during the straightening of the ingot.

The design of the annular guide cams 31 combined with the adjustability of the clamping rollers 35 is such that the mould cavity can have a slightly greater width transversely of the plane of the rotor 9 at the entrance end of the mould channel 38 and that this transverse width will gradually be decreased towards the discharge end of the mould channel. This reduction in transverse width of the mould channel will effectively take care of the shrinkage of the cast ingot.

It is an important feature of the invention that the location of the tundish 42 is located at a convenient height above floor level and has its outlet located directly above the open end of the mould channel 38 and a relatively short distance above to provide gravity flow into the mould channel.

More than one arcuate mould channel 38 can be provided in the mould segments 24 thereby permitting the production of several castings simultaneously.

What I claim is:

1. A rotary type continuous casting machine comprising a circular rotor having a peripheral rim, means to rotate the said rotor, a series of radially disposed half mould segments pivotally mounted on opposite sides of the said rotor and aligned in opposing pairs in planes normal to the axis of the rotor, annular guide cams means mounted on the said rotor holding the said opposing pairs of half mould segments apart for a sector of the machine and holding the half mould segments in closed relation in the remaining sector of the machine, the said opposing half mould segments when in closed relationship forming at least one open ended arcuate channel, locking means to hold the said opposing half mould segments on the rotor, when in their closed position, against movement in the direction of the said rotor, and means to pour molten metal into the said arcuate channel shaped by the closed half mould segments.

2. A rotary type continuous casting machine as set forth in claim 1 in which each of the said pivotally mounted mould segments includes a roller rotatable about an axis parallel to the radially pivot mould segments and the cam guide means includes a pair of annular cams one on each side of and spaced from the said rotor each of said annular cams having a channel shaped section within which the said rollers run.

3. A rotary type continuous casting machine as set forth in claim 1 in which the said annular channel cams each consist of two arcuate sections, one of which has its flanges disposed in a plane parallel with the periphery of the said rotor to hold the said half mould sections in their closed position and the flanges of the other of said two sections are disposed in a plane at an angle to the plane of rotation of the rotor to hold the said half mould sections in their open position, and interconnected offset channel members connecting adjacent end portions of the said arcuate sections, the said offset channel members permitting transitional movement of the said rollers from one arcuate member to the other.

4. A rotary type continuous casting machine as set forth in claim 3 in which the said annular channel cams each consist of two arcuate sections, one of which has its flanges disposed in a plane parallel with the periphery of the said rotor to hold the said half mould sections in their closed position and the flanges of the other of said two sections are disposed in a plane at an angle to the plane of rotation of the rotor to hold the said half mould sections in their open position, and interconnected offset channel members connecting adjacent end portions of the said arcuate sections, the said offset channel members permitting transitional movement of the said rollers from one arcuate member to the other.

5. A rotary type continuous casting machine as set forth in claim 1 in which the said locking means includes a series of transverse keyways in the peripheral rim of the said rotor located parallel with the axis of the rotor, and a key in each of the said half mould sections, the keys in each opposing half mould section fitting into one of the keyways on the rim of the rotor, the said keys and keyways locking the half mould sections from movement in the circular direction of the rotor.

6. A rotary type continuous casting machine as set forth in claim 1 in which a series of adjustable clamp rollers maintain the said opposing pairs of mould segments closed when the said segments are in the closed position.

7. A rotary type continuous casting machine as set forth in claim 5 in which the said adjustable clamp rollers are set to maintain a wider transverse width of mould
cavity at the molten metal end of the arcuate casting channel and effect a decrease in the transverse width of the mould cavity at the discharge end of the arcuate casting channel.

8. A rotary type continuous casting machine as set forth in claim 1 in which the individual mould segments are provided with a cooling water channel and cooling water feed and discharge passages are formed in the said rotor and are connected to the cooling water passages in the said mould segments by flexible connections.

9. A rotary type continuous casting machine as set forth in claim 1 in which the said rotor includes a pair of annular face plates, one disposed on each side of the rotor and the said half mould sections each include a radial arm pivotally mounted on individual brackets on said annular face plates.

10. A rotary type continuous casting machine as set forth in claim 1 in which the said means to pour molten metal into the said arcuate casting channel is a tundish located between the open half mould segments immediately above and having its outlet aligned with the adjacent open end of the arcuate casting channel.

11. A rotary type continuous casting machine as set forth in claim 1 in which the mould cavity of the said mould segments are arcuate in shape and the inner radius of the arcuate mould cavities have a series of depressions, each of which taper off radially outwards.

12. A rotary type continuous casting machine as set forth in claim 1 in which the said half mould segments each have two or more arcuate shaped half mould cavities.

13. A rotary type continuous casting machine as set forth in claim 12 in which the said means to pour molten metal into the said arcuate casting channel is a tundish located between the open half mould segments immediately above the 2:30 o'clock position of the machine and having its outlet aligned with the adjacent open end of the arcuate casting channel.

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