APPARATUS FOR THE CONTINUOUS CASTING OF MOLTEN METAL

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This invention relates to the continuous casting of molten metal such as steel. Continuous casting is the production of a casting many times the length of the mold in which it is produced.

The invention more particularly relates to a method and apparatus which provides great flexibility and versatility in the casting process. The flexibility and versatility resides primarily in the use, interchangeably on the same casting machine, of:

(1) One or a sequence of ladles (independently or simultaneously) in association with two single-stream tundish boxes and two molds; and

(2) One or a sequence of ladles in association with one multiple-stream tundish box and a plurality of molds.

Thus the method and apparatus provides for the selection, in a single piece of equipment, of several distinct modes of operation which have different and distinct utility. And, in addition, the equipment makes possible longer uninterrupted operation since it may be used for sequence casting, i.e. casting a plurality of heats or ladles into one continuous strand, to the extent that heat timing and scheduling will allow.

In the continuous casting operation there is always a possibility that metallurgical defects such as slag fragments, or process failures such as mold coolant or lubrication disturbances, may cause a breakout. A breakout is a break in the solidified outer portion of the cast bar adjacent to the still molten or liquid central portion of the bar in the mold. Thus the molten interior is allowed to penetrate the hardened outer portion and the continuity of the strand is interrupted. The equipment must be shut down for time-consuming clean-up and subsequent start-up operations. Because furnace production is carefully timed to supply the normal casting capacity of the casting equipment and furnace heats can be kept in a molten state only a limited time (roughly 40—50 minutes), a breakout may result in the loss of several heats.

The present invention assures continuous operation (and casting of the furnace heats as they are produced) in spite of a breakout. Thus it significantly reduces the economic consequences of a breakout. The reduction is made possible by the provision of at least two strands. Two strand capability is derived from the provision of two molds, each with independently operable bar or strand withdrawal apparatus, and a set of interchangeable tundish boxes which includes one double-stream tundish box and two single-stream tundish boxes.

The pair of molds and set of tundish boxes makes the two interchangeable modes of operation referred to above possible. One mode is independent operation of both molds from separate tundish boxes and ladles. Thus the mode consists of two complete and independent strand forming means operating side-by-side. If each strand is cast at a rate sufficient to use all of the molten metal in its respective ladle before it has been in the ladle, this mode is the most efficient procedure because it requires only one starting bar and produces only one end crop per heat or ladle. On the other hand, the drawing speed required is high which increases the chance of breakout and requires greater control of the process parameters such as the coolant temperature, rate of mold oscillation, and mold lubrication.

The second mode is the operation of both molds from one double-stream tundish box and one ladle. This mode has the advantage of requiring only one ladle carrier and only one tundish box. It permits lower drawing speeds and therefore reduces the risk of breakout and is less sensitive to process parameters. In case of a breakout, the discharge nozzle feeding the affected mold can be plugged and the remainder of the bar can be used without interruption in formation of the other strand.

Depending on variables in day-to-day operation, such as labor, purity of the molten metal, availability of raw materials, and production demand, it may be desirable to use one mode or the other. The present invention thus provides the advantage of being able to vary production as appropriate in view of the variables referred to.

It will be understood that the crux of the invention is that the same casting machine can be used either as a single-strand machine or as one double-strand machine, merely by changing the position or arrangement of the tundishes and ladles. In the preferred embodiment herein-after described, it will be understood that tundishes can be placed either in the arrangement of FIG. 3 or in the arrangement of FIG. 5, on the same machine, as desired. It will be readily clear to those skilled in the art that for that matter, the tundishes of FIG. 3 can both be tundishes just like that of FIG. 8 but with one of their discharge orifices plugged.

As an additional advantage, the apparatus has the capability of permitting sequence casting, to the extent that heat timing and scheduling will allow, since it permits ladle changeover in less time than it takes the tundish box to empty. Sequence casting requires only one starting bar and produces only one end crop per strand sequence, and accordingly represents an additional advantage.

Apparatus for the continuous casting of molten metal was first disclosed in 1865 in United States Patent No. 49,073, issued to Sir Henry Bessemer. Since then, the art has developed considerably, particularly as related to the continuous casting of non-ferrous metals such as aluminum and copper. In roughly the last ten years considerable effort has been directed to the continuous casting of ferrous metals, particularly in Europe and Asia. The continuous casting of steel in the United States was begun, on a production level, in about 1962.

The development and state of the art of continuous casting of non-ferrous as well as ferrous metals is well stated in a 1964 publication of the Association of Iron and Steel Engineers, Pittsburgh, Pa., entitled "Continuous and Pressure Casting."

The continuous casting of ferrous metals is generally more difficult than the continuous casting of non-ferrous metals. As compared to non-ferrous metals, ferrous metals have a higher melting point, a higher specific heat, and a lower rate of thermal conductivity. Accordingly, the continuous casting of ferrous metals is more sensitive than the continuous casting of non-ferrous metals because of the higher temperatures required to maintain the metal in a molten state, and the deeper liquid zone in the mold due to the lower rate of thermal conductivity. Methods and apparatus for continuous casting of non-ferrous metals, accordingly, must be more versatile and flexible in the rate at which molten metal is used from a ladle or ladles and withdrawn from the mold or molds to avoid hardening in the ladles or tundish boxes and to produce a homogeneous, sound, and continuous bar.


In the case of the Junghans apparatus, changeover from one ladle to another is made by reciprocally moving the ladles and supporting racks on straight parallel tracks. Some interruption in flow of molten metal into the mold...
occurs. In the Namy apparatus, changeover is made by pivoting the tundish boxes while the ladles remain stationary next to one another. The pivoting of the tundish boxes, though satisfactory for the immediate objective of changing from one ladle to another, limits verticality and restricts the location of the tundish boxes due to the stationary mechanism about which the tundish boxes pivot. Accordingly, movement of the tundish boxes through a series of stations such as a tundish preheating station, a tundish dump or cleaning station, and a tundish production station, is severely limited.

It is the object of the present invention to provide multi-strand continuous casting apparatus which can be selectively used in either the independent mode or simultaneous mode described above.

It is another object of the present invention to provide a method and apparatus for the continuous casting of molten metal which is versatile and flexible in the rate with which the molten metal may be used or formed into bars.

It is a further object to provide a method and apparatus for the continuous casting of molten metal which allows a changeover or transition from one heat or ladle of molten metal to another ladle without interrupting the casting flow into the mold, to thereby produce a continuous casting formed integrally from the two heats or ladles without interruption.

It is a further object to provide a method and apparatus for accomplishing an uninterrupted transition or changeover, as described above, without restricting subsequent movement of the tundish box or boxes from divergent and distinct cleaning and preheating stations.

It is a further object to provide apparatus for the continuous casting of molten metal which includes and is characterized by a turret consisting of one or more ladle carriers mounted for pivotal movement about a vertical axis and adapted to receive and support a ladle therein.

It is a further object to provide apparatus for the continuous casting of molten metal, consisting of a turret as described above, a pair of molds, means for continuously withdrawing solidified metal from the molds, and a set of tundish boxes for serving the molds and the ladles, to thereby provide great flexibility and versatility in the rate of discharge of molten metal from the molds and allow uninterrupted transition from one ladle to another.

Each of the above objects is fulfilled by the embodiment shown in the drawings wherein:

FIG. 1 is a side or profile view of the continuous casting apparatus;

FIG. 2 is a top view of the apparatus shown in FIG. 1 with the ladles removed and with a portion of the ladle carriers broken away;

FIG. 3 is an enlarged top view of the tundish boxes, overflow system, and ingot mold shown in FIG. 2;

FIG. 4 is a front view of the tundish boxes, overflow system, and ingot mold shown in FIG. 3 and, in addition, shows two molds (one in section) and the tundish box mounting track;

FIG. 5 is a top view of the turret which characterizes the changeover invention. It shows the ladle carriers, the ladle carrier track, the tundish mounting track, and means for pivotally moving the ladle carriers about a vertical axis;

FIG. 6 is a side view of the apparatus of FIG. 5 and shows a ladle about to be seated on the ladle carrier. FIG. 6 also shows the drive means for pivotally moving the ladle carriers about a vertical axis and it shows the ladle carrier locking mechanism;

FIG. 7 is a fragmentary view taken on the line 7—7 of FIG. 6 and shows the solenoid actuated release for the ladle carrier locking member and the relationship between the locking member, the solenoid, and the ladle carrier track;

FIG. 8 is a top view of a double-stream tundish box which is of sufficient width for simultaneously serving two molds; and

FIG. 9 is a side view of the tundish box shown in FIG. 8 and shows the means for mounting the tundish box to the tundish box track and the relationship between the ladle, tundish box and mold.

The invention, described generally and in detail below, comprises apparatus for the continuous casting of molten metal and includes a mold, means for continuously withdrawing solidified metal from the mold, a tundish box disposed above the mold, and adapted to receive molten metal from the ladle and discharge the molten metal over the mold, a ladle carrier adapted to support the ladle, and means for mounting the ladle carrier for pivotal movement about a vertical axis in a plane above the tundish boxes and the mold, to thereby allow positioning of the ladle over the tundish box for discharge into the tundish box.

The invention may be generally understood with reference to FIG. 1. The continuous casting apparatus includes a pair of ladle carriers 11a and 11b mounted in independent pivotal movement about the vertical axis 12 of center post 13. Each of the ladle carriers is adapted to receive and support a ladle 14. A tundish box 15a is mounted below the plane defined by arcuate movement of ladle 14 (with the pivotal movement of ladle carrier 11a). Tundish box 15a is also mounted for arcuate movement about vertical axis 12 and has a discharge orifice or opening (not shown in FIG. 1) directly above mold 16a. Mold 16a may be oscillated in a means of oscillating arm 17a, motor 18, and gear box and eccentric 19. An oscillation of one inch is preferred at a rate of 60 oscillations per minute. A series of rollers 21 are provided and accurately positioned to guide the solidified bar from the mold 16 to straightener rollers 22. The general operation of the continuous casting apparatus begins with the placement of ladle 14 on ladle carrier 11a. Molten metal is then discharged from ladle 14 by opening the ladle stopper as provided for by stopper apparatus 23. A stream of molten metal M flows from ladle 14 into tundish box 15a which serves as a reservoir. The stream M is discharged from tundish box 15a into mold 16a where it solidifies. Mold 16a may be oscillated and lubricated to avoid the formation of a bond between the solidified metal and the mold. Solidified metal is continuously withdrawn from mold 16a by means of rollers 21 and 22. After passing through rollers 22, the solidified metal is sheared to appropriate length on a runoff table.

Though not described immediately above, the casting apparatus includes a pair of members where but one member is described for simplicity in the general description of the apparatus. Thus, with reference to FIGS. 2, 4 and 5, tundish box 15b and mold 16b provide for double-stream or double-strand production.

The apparatus of FIG. 1 includes an overflow system which may receive overflow, if any, from tundish boxes 15a and 15b and a launder 24 which is capable of intercepting the discharge from the tundish boxes. The overflow system includes two laterally movable chutes 25a and 25b, an overflow basin 26, a basin discharge chute 27, and an ingot mold 28. Launders 24a and 24b (see FIGS. 2 and 3) are pivotally mounted to basin 26 below tundish boxes 15 and are pivotable to intercept the discharge (see 24b, FIG. 3) or avoid the discharge (see 24a, FIG. 3) from the tundish boxes 15 as may be desired. Launders 24 are used at start-up until the discharge from the tundish boxes becomes clear.

Molds 16a and 16b are cooled by means of coolant 29 circulated from reservoir 30 through mold cavities 31.

The apparatus also includes means for intercepting the discharge at the mold and the solidified bar from the mold at start-up. The initial withdrawal means, shown in FIGS. 1 and 2, dummy bars 32a and 32b mounted for storage on wheels 33a and 33b. Dummy bars 32a and 32b are fed through molds 16a and 16b respectively, and through rollers 21 and 22. The trailing end is left in mold 16 and the initial discharge of molten metal into mold 16 solidifies about
dummy bar 32. The dummy bar is then withdrawn and leads the solidified metal through rollers 21 and rollers 22 for eventual exposure. After initial exposure, dummy bars 32a and 32b are no longer used and are stored as shown in FIG. 1.

The apparatus described is mounted on a frame 34 which supports turret 35 and operating platform 36 above floor 37. With the foregoing general description of the apparatus and its operation, the specific design of the various members may be conveniently understood.

The turret which characterizes the present invention appears in FIGS. 1-6. Ladle carriers 11a and 11b are pivotally mounted centrally. 13 and retained in place by means of cap 38. A bearing 39 (shown in FIG. 6) insures smooth pivotal movement of arms 11a and 11b about center post 13.

Ladle track 40 is disposed concentrically about vertical axis 12 and center post 13 and is welded to turret platform 41. Track 40 is engaged by wheels 42 which are mounted for rotation about a radial axis passing through vertical axis 12. Two wheels 42 are provided for each ladle carrier as best seen in FIG. 5. With reference to FIGS. 5 and 6, wheels 42 are mounted to ladle carriers 11a and 11b by means of wheel mounting brackets 43. Wheel mounting brackets 43 locate wheel pin 44 radially of vertical axis 12 and center post 13. Thus ladle carriers 11a and 11b are independently pivotally mounted for 360° movement about vertical axis 12 as wheels 42 engage track 40.

As best seen in FIGS. 3, 8 and 9, tundish boxes 15a and 15b are mounted on turret platform 41 by means of tundish track 45. Tundish track 45 is welded to turret platform 41 concentrically with vertical axis 12. It includes an upper track 46, and a lower track 47. Tundish boxes 15a and 15b are mounted to tundish box arms 48a and 48b which may telescope. An upper pair of tundish box arms 49 is mounted to arm bracket 50 for rotation about a vertical axis. A second upper pair 51 is mounted to bracket 50 for rotation about a radial axis and a lower set 52 is mounted to bracket 50 for rotation about a vertical axis. As best seen in FIG. 5, upper wheels 49 engage the inner vertical edge of track 46. Wheels 51 engage the upper horizontal surface of track 46. Lower wheels 52 engage the outer vertical surface of track 47.

Thus tundish boxes 15a and 15b are hung on track 45 and may be arcuately moved about vertical axis 12. The arcuate movement of tundish boxes 15a and 15b provides for greatly divergent and widely divergent tundish box stations. Thus tundish boxes 15a and 15b may be disposed at a production station, as shown in FIGS. 2 and 3, or in a preheat or cleaning station noted in FIG. 2.

Ladle carriers 11a and 11b are provided with a drive mechanism and locking means shown in FIGS. 5, 6 and 7. The ladle carrier drive means includes a motor and gear reducer 53a and 53b mounted to ladle carriers 11a and 11b respectively. Output shafts 54a and 54b extend vertically through ladle carriers 11a and 11b respectively and are rotatably mounted thereto by means of bearings 55a and 55b. Spur gears 56a and 56b are keyed to the lower end of output shafts 54a and 54b respectively and engage internal gear 57.

Internal gear 57 is welded to turret platform 41 and disposed concentrically about vertical axis 12. Thus spur gears 56a and 56b, when driven by motors 53a and 53b respectively, engage internal gear 57 and cause independent pivotal movement of ladle carriers 11a and 11b about center post 13.

Ladle carrier locking means is provided to lock ladle carriers 11a and 11b in two production stations and one loading station. The locking means consists of a pair of gussets 58 which are mounted on the inner side of ladle track 40 at three places and two places on tundish boxes 15a and 15b (FIG. 2) and one loading station substantially opposite the production stations. Ladle carriers 11a and 11b are provided with a latch member 59a and 59b respectively. Latch members 59a and 59b are pivotally mounted by means of pins 60a and 60b. Due to their configuration and the location of pins 60a and 60b, latch members 59a and 59b are urged by gravity into contact with the inside face of ladle carrier track 40. The naturally hanging position of latch members 59a and 59b is shown in FIG. 6 with the lower vertical edge 61 thereof in contact with the inner vertical surface of track 40.

Thus as ladle carriers 11a are pivoted about center post 13, edge 61 of latch member 59 rides in contact with track 40 until urged inwardly by gussets 58. When latch member 59 rides over the leading part of gusset 58 it comes in the space between the pair of gussets and locks the ladle carrier 11a. As ladle carriers 11a are pivoted through 360° on track 40, the locking mechanism serves to automatically lock each of the ladle carriers at two production stations and one loading station.

Ladle carriers 11a and 11b are released by means of a solenoid 62 provided in association with each station. As shown in FIG. 7, solenoid 62 includes solenoid plunger 63 which extends radially through track 40. Solenoid plunger 63 has a withdrawn position in which it is coincident or flush with the inner vertical surface of track 40 as shown in FIG. 7. When actuated, solenoid plunger 63 has a stroke which pushes latch member 59 out of locking engagement with gussets 58 to thereby release the locking member and ladle carrier. The overflow system appears in detail in FIGS. 3 and 4. It includes a pair of chutes 25a and 25b, an overflow basin 26, an overflow basin chute 27 and an ingot mold 28. Chutes 25a and 25b may be positioned longitudinally of overflow basin 26 by means of chutes brackets 64 which accept vertical pins (not shown) extending downwardly from chutes 25a and 25b. Thus chutes 25a and 25b may be positioned to catch tundish overflow, as shown in FIGS. 3 and 4. The overflow system insures complete utilization (though used in an ingot mold and not in a continuous operation) of molten metal and provides for additional flexibility and versatility in the use of the apparatus.

A double-stream tundish box 65 is shown in FIG. 8. It is mounted the same as tundish boxes 15a and 15b and has sufficient width to serve two molds. For that purpose it contains two spaced discharge orifices 66a and 66b which are spaced a distance equal to the spacing of molds 16a and 16b. Thus double-stream tundish box 65 directs discharge simultaneously into molds 16a and 16b.

As shown in FIGS. 1 and 4, mold 16 is preferably formed with a refractory inner liner 70. Tundish boxes 15a and 15b as well as all the double-stream tundish box 65 are formed with a brick inner lining 71 and are provided with overflow troughs 72 as shown particularly in FIGS. 1 and 3. The overflow troughs 72 may be plugged as desired.

The apparatus described in detail above is especially versatile and flexible in its use. It provides means for continuously casting molten metal according to a number of related novel methods. Thus, as described previously, the apparatus may be used with one or a sequence of ladles containing molten metal and one or a pair of tundish boxes.

More particularly one method of continuously casting molten metal comprises filling ladle 14 with molten metal, arcuately moving the ladle about vertical axis 12 on ladle carrier 11 into a position above a tundish box 15 and mold 16, discharging the molten metal from ladle 14 into tundish box 15 and from tundish box 15 into mold 16, and cooling the molten metal in the mold 16 and continuously withdrawing the solidified metal from mold 16 by means of rollers 21 and 22. A series of ladles 14 may be sequentially positioned in tundish box 15 to provide a continuous discharge of molten metal from tundish box 15, the molten metal having been contained in both of
the ladles. Thus a continuously cast bar may be derived from a plurality of ladles.

The uninterrupted transition from one ladle to another is made by arcuately moving the first ladle about vertical axis 12 from its discharge position above tundish box 15 and arcuately moving a second ladle about vertical axis 12 into the position formerly assumed by the first ladle and then discharging molten metal from the second ladle into tundish box 15 during the duration of the first ladle stream. The term first ladle stream refers to the discharge from tundish 15 into molten metal from the first ladle. Thus, although a transition from one ladle to another is made, the discharge from tundish box 15 is continuous due to its function as a reservoir, and the critical timing with respect to the discharge from the second ladle.

Additional versatility is provided by a method for continuously casting molten metal which utilizes two tundish boxes and two molds. The method comprises filling a ladle 14a with the molten metal, arcuately moving a first ladle 14 about vertical axis 12 into a position above a first tundish box 15a and mold 16a, discharging the molten metal from the first ladle into first tundish box 15a and mold 16a, cooling the molten metal in mold 16a and continuously withdrawing it therefrom, and concurrently arcuately moving a second ladle 14 about vertical axis 12 into a position above a second tundish box 15b and mold 16b, and simultaneously discharging the molten metal from the second ladle into second tundish box 15b, mold 16b, and withdrawing solidified metal therefrom.

An additional method for continuously casting the molten metal is characterized by double-stream tundish box 65. The method comprises filling ladle 14 with molten metal, arcuately moving ladle 14 about vertical axis 12 into a position above tundish box 65 and a pair of spaced molds 16a and 16b, discharging molten metal from ladle 14 into tundish box 65 and from tundish box 65 simultaneously through discharge orifices 66a and 66b into molds 16a and 16b, and cooling the molten metal in each of the molds 16a and 16b and simultaneously withdrawing solidified metal therefrom.

And finally, the double-stream tundish box may be used in association with a sequence or plurality of ladles for continuous casting. Such a method comprises filling a plurality of ladles 14 with molten metal, arcuately moving a first ladle about vertical axis 12 into a position above tundish box 65 and molds 16a and 16b, discharging the molten metal from the first ladle into tundish box 65 and from tundish box 65 simultaneously into each of the molds 16a and 16b to thereby define a plurality of first ladle streams, cooling the metal in each of the molds 16a and 16b and continuously withdrawing solidified metal simultaneously from each of the molds, arcuately moving the first ladle about vertical axis 12 out of its discharge position above tundish box 65, arcuately moving a second ladle about vertical axis 12 into a discharge position above tundish box 65, and discharging molten metal from the second ladle into tundish box 65 during the duration of the first ladle stream to thereby provide for an uninterrupted transition from one ladle to another.

The various methods described above allow a variation of the rate of use of the molten metal. Thus with metals requiring slow casting speeds, double-stream production may be utilized to form bars and thereby use the molten metal before it has any opportunity to solidify in the ladle. The other methods described may be utilized to vary the rate of use of molten metal to an even greater extent.

Moreover, the method of changing over from one ladle to another, characterized by arcuately movement of ladles about vertical axis 12, provides for truly continuous casting within the limits referred to above. Thus a bar of indefinite length may be produced from a plurality of ladles or molds.

The formation of a solidified steel bar by the use of the apparatus and methods is accomplished at a rate of withdrawal from molds 16 of about eight to ten feet per minute. The rate of withdrawal may vary considerably, however, as a function of the cooling characteristics of the metal being cast and the length of time available to use up molten metal in the ladle to thereby avoid premature solidification in the ladle. Molds 16 are preferably formed with a mold cavity of 4½ inches square.

Ladles 14 are preferably filled with twelve to fourteen tons of molten metal at the furnace and then moved into position on ladle carrier 11 by means of a crane hook 73 shown in FIG. 6. The arcuate movement of the ladles is accomplished by the ladle carrier drive mechanism described previously.

Upon completion of the casting process the hardened bar is cut by shear 74 and placed on runout table 75.

Having thus described my invention, I claim:

1. Continuous casting apparatus comprising:
   a plurality of independently operable spaced molds
   means for forming strands of solidified metal;
   a multiple-stream tundish box having a plurality of discharge openings spaced to register with said spaced molds;
   a plurality of single-stream tundish boxes, each of said single-stream tundish boxes having a single discharge opening therein;
   means for mounting said tundish boxes and for selectively interchangeably moving said tundish boxes into and out of a position with the discharge openings thereof in registry with said molds; and
   means for discharging molten metal into said tundish boxes, including ladle carrier means mounted for pivotal movement about a vertical axis in a plane above said tundish boxes and said molds.

2. Apparatus for the continuous casting of molten metal comprising:
   a plurality of spaced molds;
   means for continuously withdrawing solidified metal from said molds;
   a plurality of tundish boxes including a multiple-stream tundish box and a single-stream tundish box;
   means for mounting said tundish boxes above said molds for independent arcuate movement about a vertical axis, into and out of registry with said molds;
   a plurality of ladle carriers;
   means for mounting said ladle carriers for independent arcuate movement about said vertical axis;
   means for arcutely selectively moving said ladle carriers about said axis; and
   means for locking said ladle carriers in registry over one of said tundish boxes.

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