A RESEARCH PAPER ON

TRANSPORTATION AND POURING OF MOLTEN METAL FOR CONTINUED CASTING

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INTRODUCTION

Continuous casting is an important process in steel production as the liquid steel is shaped into blooms and billets without rolling. This casting process has to do with the pouring of steel from a tundish which is a large vessel to hold the molten liquid into a vertical water-cooled copper mold so that it solidifies as it continuously gets pulled out [1].

Continuous casting is the most widely used process to manufacture steel, accounting for 96% of steel in the world (Brussels: World Steel Association, 2018). Thus, even small improvements to this process can greatly have an impact on the industry. During continuous casting, molten steel flows into the mold cavity through a submerged nozzle and freezes against the water-cooled mold plates in the presence of turbulent fluid flow, argon gas injection, transport and capture of particles, superheat transport, and thermal–mechanical behaviour[3], and it finally solidifies into a semi-finished solid shape, such as a slab, bloom, or billet.

Molten metal from the smelting furnace is usually poured into a ladle, from which the metal is then poured from the lip at the top of the ladle when the ladle is of small capacity.

When the ladle is larger, metal is poured through a refractory nozzle at the bottom of the ladle. The nozzle can be closed from inside the ladle by a refractory stopper. Devices without stoppers are also widely used. Here, the ladle's nozzle is closed from the outside by a refractory plate. The plate, which had an orifice, can be moved so that the orifice coincides with the nozzle, thus allowing the metal to flow out.

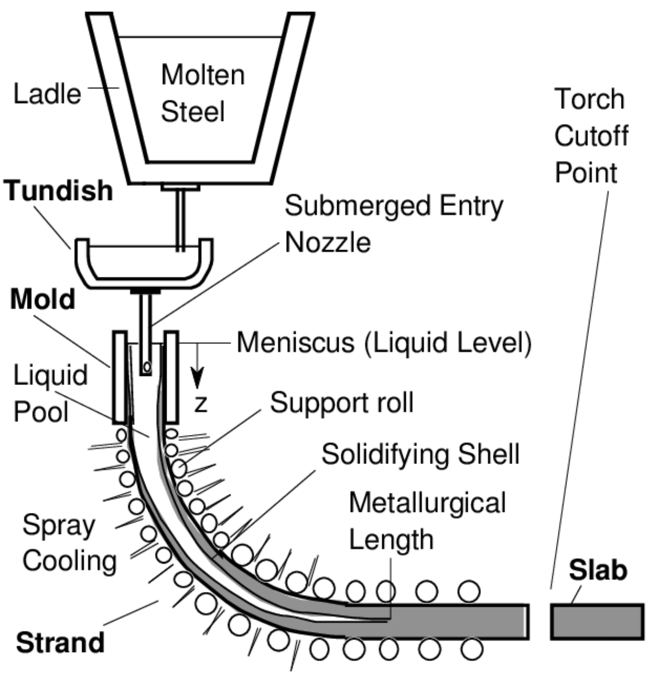

Fig. 1

After the mold is filled, the ladle opening is closed and the ladle is moved by crane to the next mold, where the process is repeated. In bottom pouring, several molds (from 2 to 60) can be filled with steel simultaneously. Here, the molds are mounted on a stool having channels lined with refractory brick. The steel from the ladle descends through the fountain into the channels of the stool and then enters the mold from the bottom. The pouring method used, depends on such factors as the steel's grade and weight and the intended use of the ingots[5].

The Challenge associated with Continuous Casting

A very notable challenge in continuous casting is the casting of steel continuously without interrupting the process and without defects. Solidification control is very important for the surface and internal quality. As for steel cleanliness, it is determined essentially already by the preceding operations in the ladle and in the tundish but can also be influenced even in the casting operation. There are some important control parameters in the solidification process and there are; steel chemistry, casting speed, mold level, mold powder, mold oscillation, liquid steel temperature, secondary cooling conditions, as well as parameters affecting the flow phenomena in the mold. The research and development work in the continuous casting field is continuing with all greatest engagement today, the major purposes being the better quality of cast product and to develop methods to cast extra difficult steel grades with special problems and requirements. Today also the energy efficiency and the ecological aspects are worth considering with special importance.

Secondary steelmaking and continuous casting are the central process phases with strong influence on the final quality of the steel products. Liquid steel processing in ladle, tundish, and mold and final solidification consist of a complicated series of successive chemical, physical, and thermal phenomena. The strict control and smooth operation of the continuous casting process are extremely important but quite challenging tasks due to scarcity of direct measurements which would describe dynamic changes in steel chemistry, temperature, flow conditions, and interactions with, e.g., covering slag, refractory materials, or mold wall.

Modelling of reactions, flow dynamics, and heat transfer can give a better understanding of different phenomena and their relations to different process parameters as well as it can advice to optimize the process run[11].

Continuous Casting Process Details

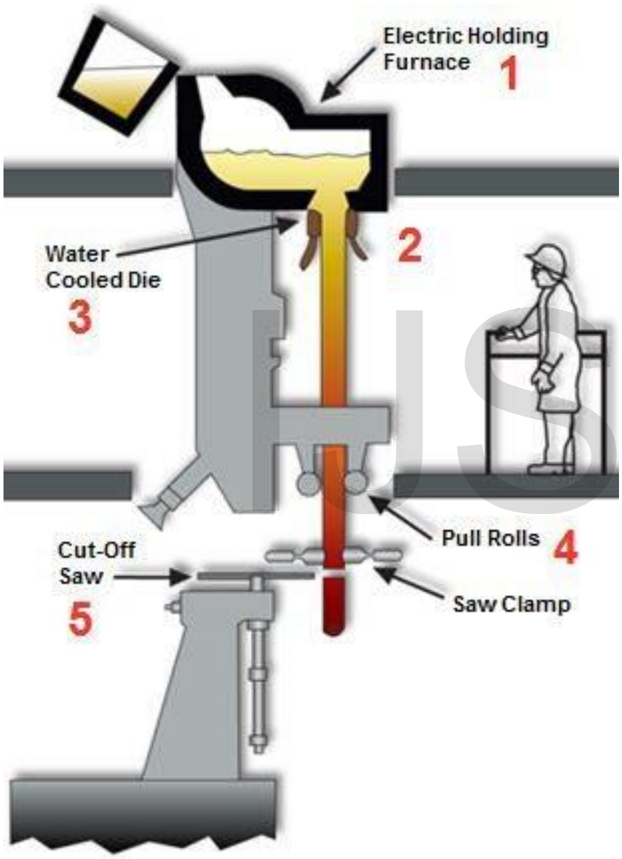

Fig. 2 (Dave olsen: what is continuous casting process)

From fig.2 above, molten metal from an induction furnace is fed directly into a mold with the required shape labelled 1. Then the molten metal enters the die through a series of holes in the upper portion of the mold. Also the heat is extracted by the water-cooled jacket surrounding the mold, and the metal is then solidified. The molten metal that is above the die serves as a riser keeping the die filled and preventing the formation of shrinkage cavities in the required finished form: which are the bar, tube or special shape as seen in the part labelled 2.

Solidification occurs in the die and then the solidified metal casting exits through the bottom of the die by means of a continuous process of short intermittent extractions performed by a mechanical device seen on the section labelled 3.

The product is then withdrawn at controlled increments and speed until the production length is met, see area labelled 4. The lengths are cut off by a travelling saw which moves with the cast shape. The standard length for continuous cast material is 144 inches as shown in the labelled part, 5 of fig. 2.

Since continuous casting operates as a true gravity fed bottom-flow casting method, the process minimizes the possible trapping of casual dirt and dross in the casting. Foreign matter in the furnace crucible floats to the top of the melt so it does not become part of the cast product[2].

1.1 Bearing unit design

The bearing unit consists of three split elements; the housing, bearing and seal. The housings are located in a V-shaped recess in the roller frame either by screws or keys. The upper part of the housing incorporates the cooling chamber, while the lower half has a connection for the lubricating grease and the cooling water. During operation, the temperatures of the housing surface may reach 400 °C. To ensure adequate cooling of the bearings, the upper part of the housing has an integral water-cooled chamber with optimised cross section. Housings are coated with a heat and corrosion-resistant paint.

The bearings are either spherical roller or cylindrical roller bearings, depending on customer requirements. Normally they are non-locating.

Spherical roller bearings consist of two axially split inner ring halves, which are pressed tightly together by two split clamping rings, four machined brass cage and spherical roller assembly halves and one outer ring half. Compensation for length variation of the driven rollers is achieved between the bearing bore and the shaft. Also the inner ring halves have a lubrication groove and holes in the bore to ensure freedom of movement.

Split cylindrical roller bearings have a full complement of rollers. As there is sufficient space available, it is possible to join directly the two inner ring halves by four screws. Axial displacement, to compensate for length variations in the driven rollers, takes place inside the bearing between the rollers and the outer ring raceway. The outer ring half has a spherical outside diameter which allows the bearing to align itself in the housing. Split cylindrical roller bearings can be made of designs where there is limited width and small cross section, making them particularly suitable for thin slab technology, which is becoming increasingly popular for sheet metal production used in car manufacture.

Seals are also introduced to prevent water, dust and scale from entering the bearing and causing damage. The conditions in continuous casting plants are amongst the most difficult of any production process; seals are also subject to high temperatures while also being required to have very high sealing efficiencies. The system used is a combination of an outer labyrinth incorporating a lamellar steel ring. For spherical roller bearings, the sealing performance can be improved by using additional split radial shaft seals[6].

1.2 Sustainable casting processes through simulation-driven optimization

In this casting process, the mold is rotated at high rotational speeds. The centrifugal force pushes the molten metal toward the boundaries of the mold. There are three types of centrifugal casting processes, namely, true centrifugal, semi centrifugal, and centrifuge casting. True centrifugal casting is used to produce tubular parts such as tubes, pipes, rings, as illustrated in Fig.2.2 The mold can be held stationary or be rotated during the filling process. The axis orientation can be either horizontal or vertical. Due to the high rotational speeds imposed, the molten metal obtains the shape of the mold.

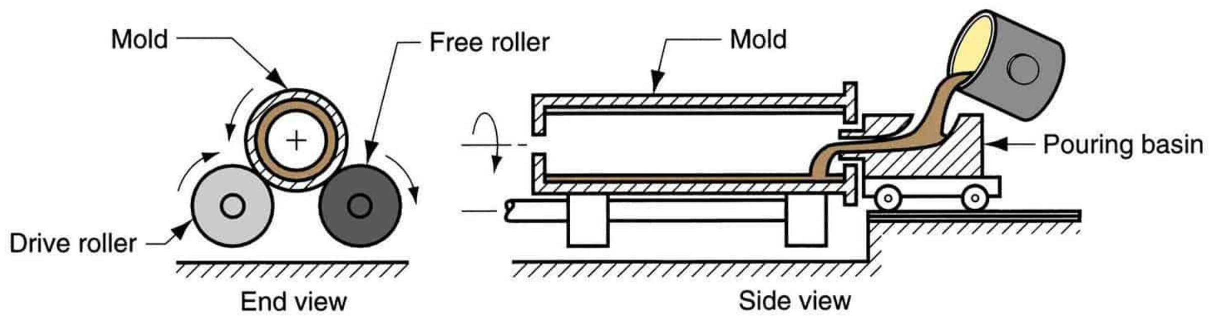

Fig. 2.2 True Centrifugal casting machine

Semi centrifugal casting differs from the true centrifugal casting with regard to the characteristics of the final part. This casting process is used to manufacture solid castings such as wheels and pulleys. Finally, in the centrifuge casting process, the part cavity is located away from the axis of rotation and the centrifugal force is exploited in order to fill in the cavity. Unlike the two aforementioned casting processes, radial symmetry is not a requirement in this process, which is suitable for producing small parts[4].

1.3 Solidification Process

Generally, the transformation of an element of liquid into solid follows a heat balance which is given by: $\rho c_p \, \partial T/\partial t = L \, \partial f_s/\partial t - QSV$

Where ρ, c_p and L are the density, the specific heat capacity and volumetric latent heat of the metal respectively. S and V in the above equation are the surface area and volume of the element, and f_s. is the fraction solid. Q is the net heat flux to/from the volume element.
This equation can be closed by specifying an f_s-t-T relationship if Q and f_s. can be identified. Q is dependent upon the thermal field caused by the structure around the element and the mold characteristics. The fraction solid f_s, depends on the solidification kinetics, which is governed by the rates of nucleation and growth. The specific conditions of the alloy chemistry and mold will govern nucleation and growth rates and thermal fields, and this in turn will determine solidification structure in terms of solid crystal size and shape, micro and macro segregation and porosity. Casting processes are carried out in a wide variety of mold types and processes[5].

1.4 The Molten metal pumps

Also called melt pumps are used for transporting liquid metal from an initial furnace or crucible to a desired final location or for forced circulation of furnaces which is critical for optimizing furnace operation to reduce energy use, improve metal yield, improve temperature and chemical homogeneity, and maximize furnace throughput.

In the installed casting factory, pump systems can be used to transfer molten aluminium from the melting furnace to a transport ladle or directly to the casting cells, using refractory-lined piping to reduce oxidation and improve operations safety.

1.5 The Right Materials used

Though almost all metals can be used for the casting, the most common ones are iron, steel, aluminium, magnesium and copper-based alloys such as bronze.

Whereas Zinc, aluminium, magnesium and brass are mostly used in die casting while aluminium alloy, brass alloy, cast iron and cast steel are associated with sand-casting materials.

Conclusion/Discussion

Nearly every engineering product we use in our everyday lives ranging from the washing machines to pillar drills from cars to bicycles are manufactured using metal parts which are most likely to be made using one of the metal casting processes. This long standing manufacturing process has improved in its precision and tolerances over the time.

Basically, castings are used to mold car engine blocks, crankshafts, power tool housings such as pillar drills, plumbing parts, turbine blades, metal statues, some gears and gearbox housings.

Of interest is the role of electromagnetism. Measurements of the surface level profile and its fluctuations are needed to understand transient phenomena related to surface defect formation in the transportation of continuous casting metal. Especially, surface level fluctuations near the meniscus are known to cause slag entrapment during initial solidification. Thus, it is important to accurately measure and control the surface level during continuous casting. To achieve this, Eddy current sensors are widely used to measure surface level for real-time control in the plant. There are other methods to measure the surface level profile like the nail board, sheet dipping, and oscillation mark measurements. Electromagnetic Mold Flow Control Sensor was developed by AMEPA GmbH and consists of a permanent magnet and pair of highly sensitive current detectors mounted behind a copper mold plate. The time delay for steel flow variations to travel between the two detectors is evaluated from the measured variations in the induced current, which is generated in proportion to the local velocity of the conducting molten steel travelling through the magnetic field. The time-dependent spatially-averaged velocity near the solidification front in that region of the mold is then output, knowing the distance between the two detectors[7-10].

Conclusively, due to the considerable mold cost and casting machine set-up, it is uneconomical to consider the continuous cast method for some special shapes in small quantities.

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