ACHIEVING BOTH HIGH QUALITY AND HIGH PRODUCTION RATES ON COMBINATION CASTING MACHINES AT MAANSHAN, P.R.C AND STEEL DYNAMICS INC., USA [1]

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Abstract

Over the last few years, combination bloom/beam blank three-strand casting machines have been successfully commissioned by SMS Demag Inc. at Maanshan Iron & Steel Co., Maanshan, PRC, and at Steel Dynamics Inc. (SDI) in Columbia City, Indiana, USA. At Maanshan, which was the first casting machine capable of producing beam blanks in Mainland China, annual production rates have surpassed anticipated levels by over 40%. The design of the casting machine equipment allowed for the capability to produce silicon-killed structural grades by open pouring via metering nozzles from the tundish to the mold as well as the utilization of submerged pouring from the tundish to the mold via stopper rods and submerged entry nozzles for high quality aluminum-killed steel grades. This machine design afforded Maanshan the flexibility in casting machine set-up to expeditiously adjust to dynamic market conditions. At Steel Dynamics Inc., the casting machine was designed to produce one bloom size and four beam blank sizes for processing through their heavy section mill into wide flange beam products. Originally, all structural products cast at SDI were silicon-killed steel grades and were open poured via metering nozzles. Although the emphasis by SDI was on the structural market, their long term goal was to become a major player in the production of high quality rails. Therefore, during the proposal and design phase of this project, no machine component design was compromised in order to insure that a high quality product would be produced on this casting machine. This production of high quality products was not only achieved in the structural products cast at SDI but since April 2003, SDI has been successfully producing high quality rails cast from a second bloom size with submerged pouring from the tundish to the mold with steel flow controlled via stopper rods. These novel types of casting machine designs allow these two facilities to efficiently produce whatever the order book dictates. This paper will explain how these two casting machines combine all of the features necessary to promote high quality, high productivity, and high machine utilization rates.

Key-words: Combination bloom/beam blank, open pouring, submerged pouring

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INTRODUCTION

In recent times, steel plants throughout the world have chosen to purchase continuous casting machines which can produce a wide variety of as-cast sizes and steel grades. Such was the case at both Maanshan and SDI. Not only were these two facilities interested in penetrating the lucrative structural market, but also to produce value-added products as well. With this in mind, SMS Demag Inc. designed and supplied continuous casting equipment to these two companies which met all of the requirements regarding high production capability as well as producing a high quality product.

Both of these respective continuous casting machines employed the latest technology to assist in high productivity, low maintenance and high quality production. High casting machine throughput rates were attained by utilizing casting machine components such as mold copper designs with high velocity mold water flows (6 – 12 meters per second), short lever arm electro-mechanical oscillators, automatic tundish and mold level control systems, automated secondary cooling systems and strand containment equipment to sufficiently support the as-cast product at the elevated casting speeds utilized at both installations.

From a quality standpoint, both casting machines utilized ceramic shrouding from ladle to tundish, regardless of steel grade being cast. Additional features which aided in the production of a high quality as-cast product are as follows: automatic tundish level control, automatic mold level control, speed-tie mold oscillation system, speed-tie secondary cooling system with cooling curve recipes developed by product size and steel grade group. Mold taper design was such that a high surface quality was achieved at high production rates. The below mold containment equipment were designed to minimize strand bulging as well as provide adequate support of the as-cast product. The placement of the withdrawal-straightener units was also based with the premise that production of a high quality product was essential. Therefore, the number of unbending points which directly impacts strand surface strain and the potential propensity of surface of cracks if improperly placed was an important feature of these casting machines. A summary of each of the continuous casting facilities will be now be presented.

MAANSHAN

The Maanshan continuous casting machine was commissioned in July of 1998. Heat sizes of 68mT were supplied by the basic oxygen furnace shop (BOF). One bloom size and two beam blank sizes are produced on this continuous casting machine. The casting machine was installed in order to replace the former ingot-making facilities at Maanshan. The basic specifications of the machine are noted in Table 1.

Table 1. Maanshan Casting Machine Basic Specifications

Annual Designed Production Rate	600,000 mT/yr
Number of Strands	3
Number of Unbending Points	3
Cast Sizes	750 x 450 x 120mm Beam Blank
	500 x 300 x 120mm Beam Blank
	250 x 380mm Bloom
Steel Grade Groups	Structural Carbon Steel
	Bridge Structural Steel
	Hull Structural Steel
	Low Alloy Structural Steel
	Low Alloy Steel
	Weather Proof Steel
Tundish Steel Flow Method	Stopper Rod or Metering Nozzle
Mold Lubrication	Mold Powder
Mold Taper	Single Taper
Mold Copper Design	4-piece Plate Configuration
Mold Level Control	10 millicurie Cesium 137 Radioactive Source by Ronan
Oscillator	Short lever arm with 10mm max stroke and 250 cpm max frequency
Containment	Foot rolls and Two Containment Zones
Secondary Cooling System	One Water-only Spray Loop & Six Air-mist Control Loops

Although the casting machine was originally designed to produce 600,000 metric tons annually, Maanshan has been able to achieve production levels of nearly 1,000,000 metric tons annually by reducing delay time and thereby increasing steel-in-mold time. As mentioned earlier, Maanshan has the capability to cast with stopper rods and submerged entry (SEN) nozzles. Maanshan not only became the first beam blank producer in Mainland China but also became the first producer to successfully cast beam blanks with an SEN. The SENs were utilized by Maanshan when casting alloy or aluminum-killed steel grades. This allowed Maanshan to cast high quality, value-added product.

The design of the casting machine also allowed Maanshan to cast different sizes at the same time. Hence, this gives rise to the term "combination casting" which implies a casting machine's design capability to cast a wide array of product types on the same machine as well as the capability of the machine to cast more than one during the same caster sequence. In order to allow for the casting of different sizes on the same casting machine, removable tundish nozzle plates are utilized. These nozzle plates, which are located on the tundish bottom, contain pouring holes which line up in the correct pouring

location of the mold size being cast. Refractory personnel prepare these plates along with the rest of the tundish based on the production schedule. Their job also entails preparing the tundish for open pouring via metering nozzles or submerged pouring utilizing stopper rods and SENs. All three of the mold sizes supplied to Maanshan have been cast with stopper rods (as well as metering nozzles).

STEEL DYNAMICS INC.

The Steel Dynamics Inc. (SDI) continuous casting machine was commissioned in April of 2002. The casting machine was a part of a Greenfield facility designed to produce over 1,250,000 metric tons of structural steel annually. Heat sizes of 110 metric tons were supplied by the electric arc furnace (EAF) shop. The caster throughput rate is 135 mT per hour. The casting machine was installed with the purpose of producing a wide array of finished wide flanged beam product for use in the construction industry. The basic specifications of the machine are noted in Table 2.

Table 2. SDI Casting Machine Basic Specifications

Annual Designed Production Rate	900,000 mT/yr
Number of Strands	3 (Expandable to four)
Number of Unbending Points	2
Cast Sizes	980 x 370 x 90mm Beam Blank
	730 x 370 x 90mm Beam Blank
	555 x 420 x 90mm Beam Blank
	430 x 260 x 80mm Beam Blank
	160 x 260mm Bloom
Additional Cast Size for Rails	250 x 320mm Bloom
Steel Grade Groups	Structural Carbon Steel
	Structural Alloy Grades
	Rail Grades
Tundish Steel Flow Method	Metering Nozzle (initial contract); Stopper Rod (Rail Bloom Contract)
Mold Lubrication	Mold Lube Oil (for tube molds) and Mold Powder (for plate molds)
Mold Taper	Parabolic (for mold tubes) and Single Taper (for plate molds)
Mold Copper Design	Tube (for blooms and small Beam Blank); Plate (for balance of sizes)
Mold Level Control	Co-60 Radioactive Source by Berthold
Oscillator	Short lever arm with 12mm max stroke and 250 cpm max frequency
Containment	Foot rolls and One Containment Zones
Secondary Cooling System	Seven Water-only Spray loops

The SDI machine has met the anticipated throughput rate of 135 mT per hour. Due to economic conditions surrounding the structural market at this time, SDI has to date been unable to fully utilize the production capabilities of the continuous casting machine. What SDI was able to do however, was position itself to become the preeminent supplier of high quality rail both within and outside of the USA. The casting machine at SDI, just as with the machine at Maanshan, was designed not only with lofty expectations for a high production facility to be installed, but also, to be a producer of high quality as-cast products as well. The initial design of the machine did its part so that when SDI decided to enter the rail business, only the quality/process enhancement pieces of equipment were required to be purchased. Namely, this included the addition of hydraulics and inert gas lines for the tundish cars to enable stopper rod casting with argon gas injection, new parabolic tapered tube molds along with Mold Electromagnetic Stirring (MEMS), a new containment section, the addition of Final Electromagnetic Stirring (FEMS), and Automation upgrades as well.

The realization is that SDI has transformed itself in Columbia City from a producer of only structural steel grade products to the premier USA supplier of high quality rail product. All of this being accomplished on the originally supplied continuous casting machine which was designed, as has been stated previously, not only for high production, but for high quality as-cast production as well.

CONCLUSIONS

When the two steel companies mentioned in this paper began planning their respective brown field (Maanshan) and Greenfield (SDI) facilities, the idea was to attempt to build continuous casting machines that were capable of producing a wide range of as-cast products predominantly for the structural market. For the design of the casting machines, this meant the rather unique opportunity to take equipment designs and process technologies which were previously utilized on high quality bloom or structural product bloom/beam blank machines and integrate them into what is now being referred to as combination casting machines. This combination of design and technology has provided both steel plants with flexible production capabilities and cost advantages that will benefit them well into the future. In a sense, irregardless of market conditions, these two facilities have the built-in design capability, in these casting machines supplied by SMS Demag Inc., Pittsburgh, PA, USA, to be profitable, highly productive and provide to their customers a product which is of the highest quality.