Increased Productivity and Quality through Conversion of Secondary Cooling to Air Mist System in Combi Caster

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The 4-strand combi caster at SMS-II of JSPL, Raigarh commissioned on 12/06/2003 is designed to produce 2 section sizes each of Beam Blank and Bloom and 4 sizes of Rounds. The caster produces low, medium and peritectic grades including micro alloys. Since 2003, the product range has widened as the demand for long products has increased. Therefore increased productivity, higher flexibility and improved product quality were required.

The machine has 5 zones in secondary cooling fitted with water only nozzles. The maximum casting speed was limited to 0.76 and 1.10 m/min for casting Beam blank of large and small section respectively. Typical quality problems in casting Beam blanks such as surface cracks in the web region could be observed.

A secondary cooling study has been conducted on all section sizes determining potential benefits of a conversion to an air-mist secondary cooling system. The main objectives were to increase current casting speeds to caster design speeds and to improve product quality with existing cooling water flows.

The encouraging results of this study led to the decision to upgrade the secondary cooling system. New headers and nozzles have been designed and were fitted onto the existing segments. The secondary cooling control instrumentation and software has been extended and redesigned to fit the new requirements. Extensive mathematical simulation for computation of solidification and surface temperature profile has been used for redesigning the secondary cooling system.

The implementation and commissioning for the beam blank format was conducted during a regular shutdown in February 2014. First hot trials have shown excellent results. The product quality was improved and the maximum casting speed was increased by 15-20 %. The quality issues in terms of surface cracks have been reduced significantly. This project demonstrates a fast and cost-effective method to increase productivity and quality by upgrading the secondary cooling system.

Introduction

The Combi caster at SMS-II of JSPL Raigarh, India is capable of casting blooms, rounds and beam blanks on up to 4 strands and was commissioned by Siemens VAI in 2003. Multiple steel grades are cast in multiple section sizes for each format reaching from low carbon to high carbon and micro-alloyed grades. In order to increase productivity and product quality, the secondary coo ling system was converted from water only to air-mist and the secondary cooling control was modernized.

The first formats to be converted were two section sizes of beam blank in February 2014.

Machine Details

The combi caster is fed by 100 t ladles in a ladle turret which is supplying steel to a 27 t tundish. The steel is processed through a submerged entry nozzle into a 800 mm curved mould which is equipped with an electromagnetic stirrer. The casting radius is 12 m in all cases and the strand support is provided by 3 segments.

Multiple segments are exchanged with change of format and section size. Both beam blank section sizes have individual foot rollers as well as individual segments 1 and 2. Segment 3 is common for all beam blank and round formats. The continuous straightener consists of 4 rolls and the strand is cut with a torch cutter after a machine length of 38.8 m.

Casting Data before Conversion

Existing casting speeds for beam blank grades were limited due to insufficient cooling intensity and quality issues of the final products. The respective maximum average casting speeds for both section sizes are given in Table X.

Beam Blank Format (mm x mm x mm)	Max Casting Speed (m/min)
355 x 280 x 90 1.1	1.1
480 x 420 x 120	0.76

***Table X :** Max. Casting Speeds before Conversion*

Local overcooling as a result of nozzle clogging, poor nozzle alignment and uneven cooling caused deformation of the flange side. The resulting flange side concavity was also a major quality issue before the conversion. Also secondary cooling was suspected as a cause for frequent break outs which decreased the productivity of the caster.

The water only nozzles installed in the caster were frequently subject to nozzle clogging which amplified the uneven secondary cooling and the according problems. Also frequent maintenance to exchange clogged nozzles was required.

Another issue which is typical for beam blank casters is the amount of running water on the loose web side of the beam blank. This frequently causes overcooling of the web face and hence promotes the formation of longitudinal surface cracks (example in Figure 1).

Figure 1 : Web Surface Cracks on Beam Blank

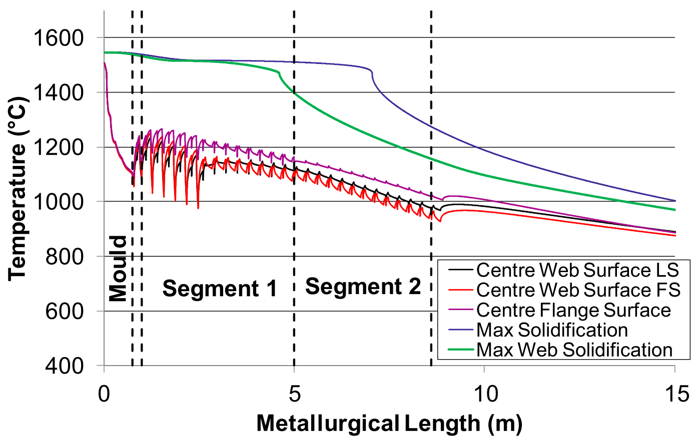
Optimisation of the Process

In order to increase the caster productivity and improve the product quality the casting and solidification process has been simulated. Existing conditions providing good quality have been used as a benchmark for the optimised secondary cooling process.

For this exercise the caster geometry and process data has been collected and implemented into a FDM Model for the simulation of the solidification process. The caster geometry includes mould length, roll positions on all sides and straightening configuration. Process data includes casting speed, superheat temperature, meniscus level, mould cooling data and secondary cooling data.

As a result the temperature profiles for all beam blank faces have been simulated. Also the critical areas of final solidification on the web side and on the cross section between web and flange side have been determined. A result for a C18 grade is shown in Figure 2. Also the critical shell thickness to contain the liquid steel minimizing bulging has been calculated and benchmarked using a simplified geometry of both section sizes as shown in Figure 3.

Figure 2 : Solidification Profile of C18 Grade for Small Beam Blank at 1.1 M/min before Conversion



During a plant visit the simulated surface temperatures on all faces have been verified with pyrometer measurements at the caster. Based on these results an optimised secondary cooling system was designed maintaining good quality at increased speeds and productivity. The water supply was to remain as existing, for segments 1 and 2 additional air-supply had to be proposed.

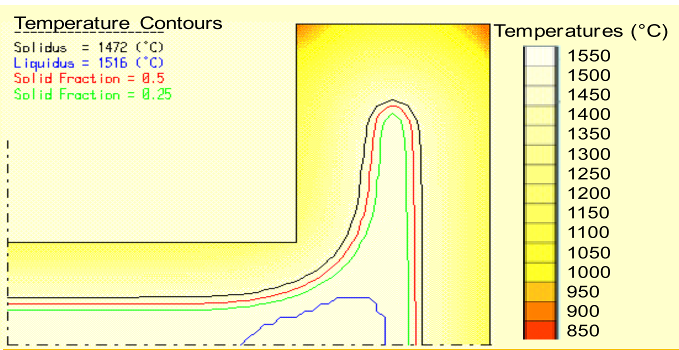


Figure 3 : Existing Temperature Profile of Simplified Beam Blank Geometry Quarter Cross Section at 2 M Below Meniscus of C18 Grade for Small Beam Blank at 1.1 M/min

Therefore the nozzle layout was modernized installing air-mist nozzles of Lechler Mastercooler and Billetcooler type in Segments 1 and 2. Utilising the increased heat transfer and the increased water turn down ratio of the new nozzle type as well as the available maximum water flow rate in each cooling zone the maximum casting speed was defined. Also the required air flow rates were defined for the airmist cooling zones at a constant air supply pressure of 2 bar.

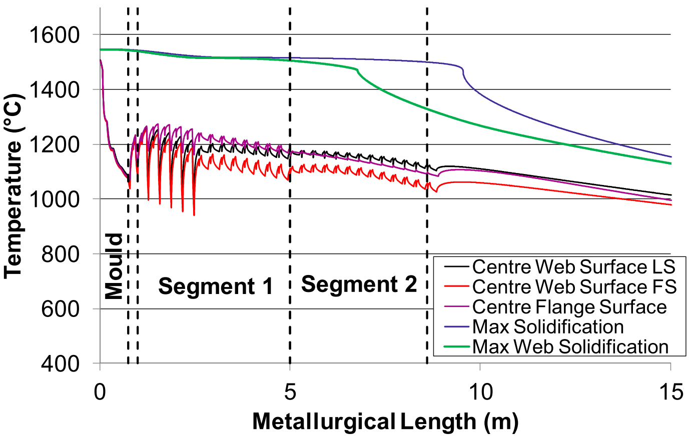
The casting speeds could be significantly increased maintaining similar solidification profiles. The recommended casting speeds with the new secondary cooling design are shown in Table 1.

Beam Blank Size (mm)	Max Casting Speed (m/min)
355 x 280 x 90	1.5
480 x 420 x 120	1.1

Table 1 : *Proposed Maximum Casting Speeds after Conversion*

The simulation result of a C18 grade at the new proposed maximum casting speed is shown in Figure 4. Although the cooling intensity could be significantly increased the solidification length of both, web side and flange side are increased as a result of the casting speed increase. However the final solidification on both sides takes place shortly after the end of support and thus the shell thickness is sufficient to reduce bulging to an acceptable level.

Figure 4 : Solidification Profile of C18 Grade for Small Beam Blank at 1.5 m/min after Conversion



Secondary Cooling Conversion

The secondary cooling system of cooling zones 2-4 in segments 1 and 2 was redesigned and converted to air-mist cooling. Therefore the nozzles, piping, instrumentation and control systems were upgraded to match the new requirements.

A new Air valve Skid shown in Figure 5 has been installed to provide air supply and control of the airmist cooling zones. The air pressure can be individually controlled for each cooling zone. Also individual strainers are installed in each air line to provide optimum air quality.

Headers for the new nozzle layout shown in table 2 were engineered and designed, providing a most maintenance friendly and wear resistant design to meet high quality standards.

The Mastercooler nozzles have been especially designed to match the process requirements including extensive testing of liquid distribution for all required operating conditions.

Figure 5 : New Air valve Skid for Air Supply of Segments 1 & 2

Table 2 : New Nozzle Layout for Beam Blank Caster

Segment	Zone	Nozzle Type
Ring	1	Water Only
1	2	Master Cooler
	3	Billet Cooler
2	4	Billet Cooler

New spray plans have been provided defining the water flow rates as a function of the casting speed for all cooling zones. Also correction factors have been supplied taking into account variations in tundish superheat and secondary cooling water supply temperature.

The piping and instrumentation diagram (PID) has been updated with the additional pipes and instrumentation. A commissioning manual has been created listing all required checks before casting.

A process manual has been supplied summarizing the new systems requirements, process data, spray plans and solidification profiles.

While secondary cooling air control had to be completely engineered designed and supplied, the water control could be maintained as before with exception of the spray headers.

New control software has been supplied and the required additional controls for the new instrumentation for air supply has been implemented. The software RS Logic-5000 (Laddre logic) by Rockwell Automation has been used for the upgrade.

Within the software new air-supply related emergency routines and spray water control factors for varying steel superheat and spray water temperature have been implemented. Commissioning

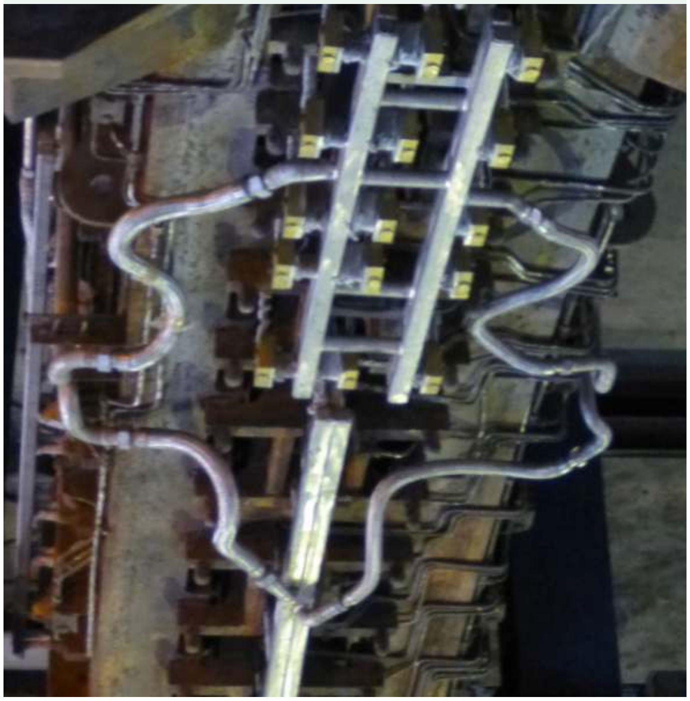
The commissioning of both beam blank formats has been successfully accomplished in February 2014. Engineering teams from Lechler supported JSPL in converting the secondary cooling systems and advised on control software programming.

Before the first cast on the newly converted strand #1 all newly installed system have been successfully cold commissioned. Cold commissioning included functionality checks of all old and new instrumentation. The new software has been tested to ensure correct flow rate and pressure control of the secondary cooling water and air supply system.

Pressure flow checks in all segments ensured correct flow rate supply of the new secondary cooling nozzles. Additional visual checks of the spray performance and nozzle alignment in all segments have been conducted.

Figure 6 shows Segments 1 & 2 with the new air-mist headers with Mastercooler and Billetcooler nozzles during cold commissioning checks.

Figure 6 : Segments 1 & 2 with New Air-mist Headers Mounted on Strand 1 During Cold Commissioning

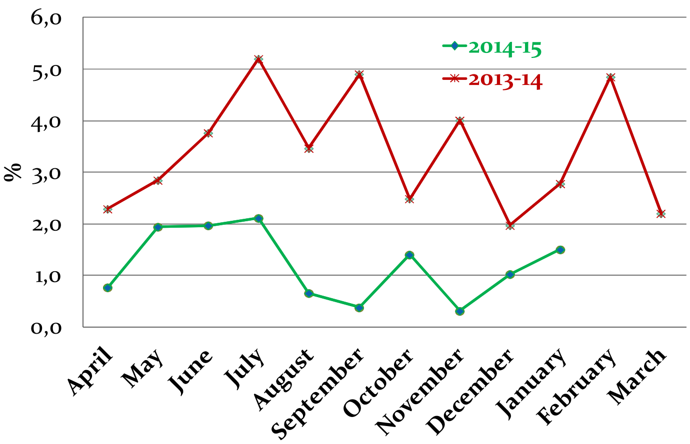


After successful cold commissioning and verification of the extended control options of the new air-mist secondary cooling system, the first beam blanks were cast in February 2014. Temperature measurements on all beam blank faces confirmed the simulated temperature profiles of the new system and validated the new aim casting speeds. Figure 7 shows a top view on the straightener during hot commissioning. Strand #1 on the right side of the picture has been converted to air-mist cooling system while the other strands were still operating with the old system. Clearly the elevated surface temperature can be seen on the picture.

Figure 7 : Top View on Straightener During Hot Commissioning of Strand 1 (Right)

First surface inspection after hot commission indicated an improved quality of the converted strand #1. There were no indications of flange face deformation and the web surface cracking was reduced to a minimum. The initial suspicion could be verified during the first year of operation. The results for longitudinal cracking are shown in Figure 8 indicate an average cracking reduction from 3.4 % before the conversion to 1.2% with the new air-mist cooling system.

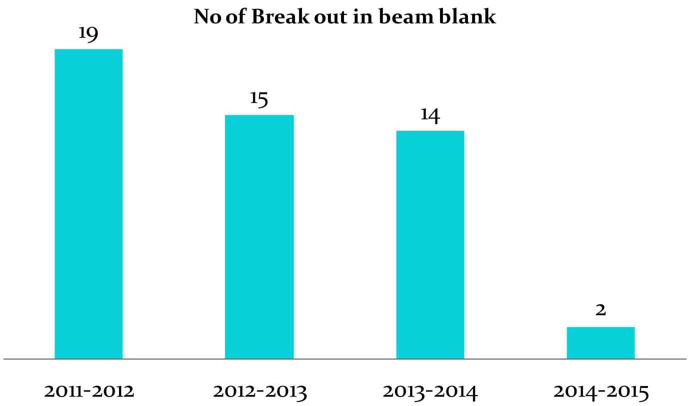
Figure 8 : Comparison of Longitudinal Cracking before (Red) and after (Green) Conversion



The problem of running water on the beam blank fixed web side was also significantly reduced which reduces overcooling of this side and hence reduces thermal strains of the material.

As a result of the optimized secondary cooling the problem of breakouts is drastically since the conversion. Until today, no breakout occurred which could be related to secondary cooling. Also the overall breakout statistic shown in Figure 9 highlights a significant reduction of breakouts which decreases maintenance and increases productivity of the caster.

Figure 9 : Number of Breakouts Before and After Conversion

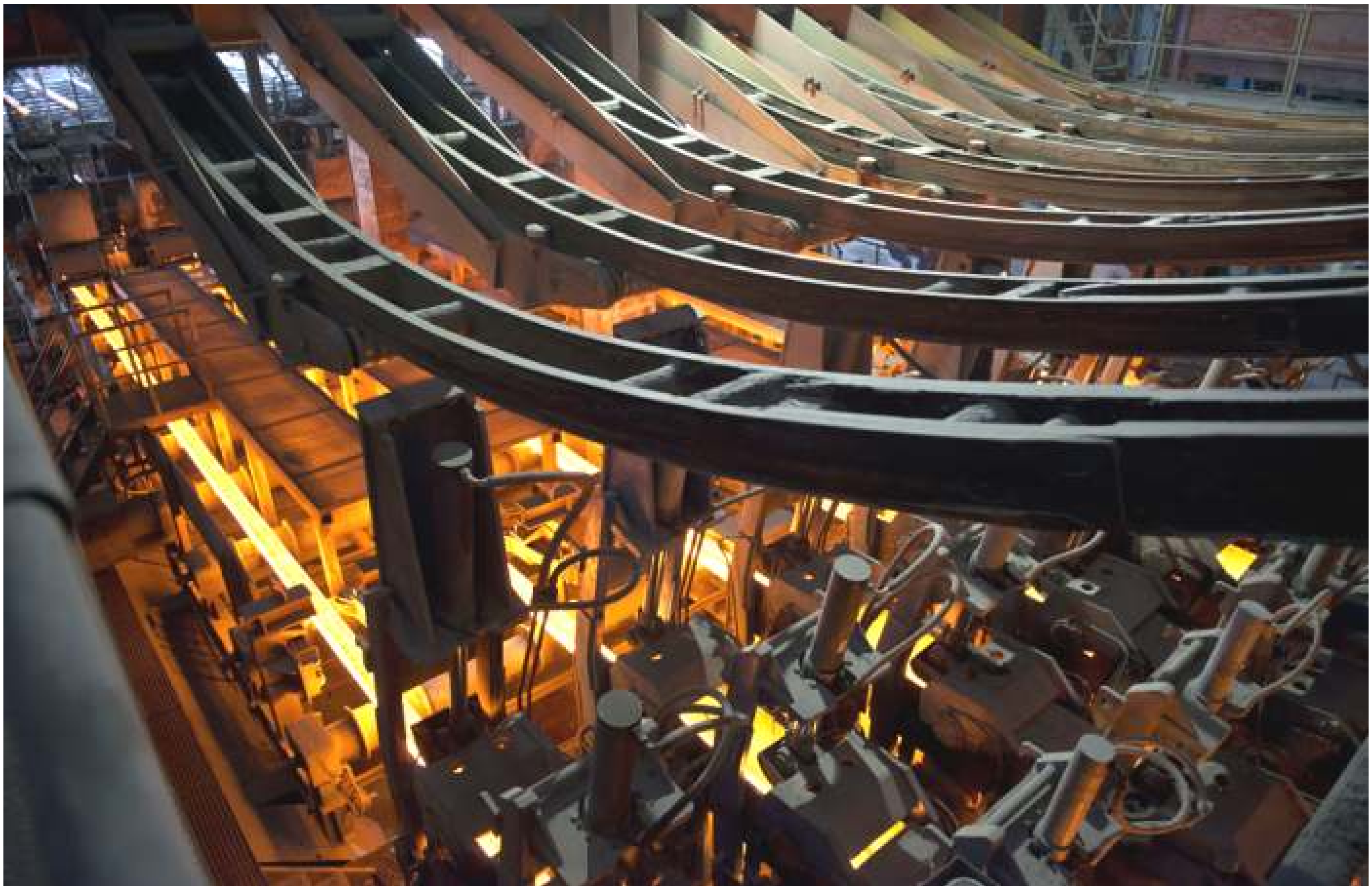


The now achievable casting speeds are matching the minimum ladle tap-to-tap time thus maximizing the productivity of the caster.

Also nozzle clogging issues were reduced to a minimum with the new air-mist nozzle layout reducing maintenance work and material costs.

Future Projects

Based on the very good results of the conversion of the beam blank



casters in terms of productivity, product quality and maintenance reduction, the conversion of the remaining bloom and round formats is planned for the near future. Also the conversion of the identical caster in SMS#3 is planned.

The resulting potential increase of the maximum casting for all section sizes based on the study is shown in table 3. The increase in productivity will be even higher since an increase in quality and reduced maintenance are expected as well.

Table 3 : Proposed Maximum Casting Speeds before and after Conversion for All Section Sizes Cast on Combi Caster

Section	Maximum Casting Speed (m/min)		Increase
	Before	New	
Small Beam Blank	1.10	1.50	36 %
Large Beam Blank	0.76	1.00	31 %
Small Bloom	0.85	1.25	47 %
Large Bloom	0.46	0.74	61 %
Round 250	1.00	1.20	20 %
Round 280	0.90	1.10	22 %
Round 305	0.85	1.00	18 %
Round 350	0.65	0.70	8 %

Conclusion

The productivity of the well-proven combi caster at JSPL Raigarh showed potential for improvement in terms of casting speed, product quality and maintenance.

In order to quantify this potential, a secondary cooling study of the combi caster has been conducted to define achievable maximum casting speeds, required water and air flow rates and pressures, nozzle layout and secondary cooling control data in order to improve the existing quality and to reduce the current maintenance costs.

The secondary system of the beam blank casters has been converted from water only to air-mist based on this study. As a result the casting speed could be increased, the product quality could be improved in terms of reduced surface cracks and reduced flange side deformation. Also the number of break outs was significantly reduced and the issue of spray nozzle clogging was eliminated.

This example demonstrates an effective way and the potential of an optimisation of a secondary cooling system and its effect on productivity, quality and maintenance.

Abbreviations

Max Solidification: Point of final solidification in area between web and flange side

Max Web Solidification: Point of final solidification on web side