Increased productivity and quality through conversion of secondary cooling to air-mist system on beam blank, bloom and round combi caster

The 4-strand combi caster at SMS-II of Jindal Steel & Power Ltd commissioned in 2003, was designed to produce two beam blank section sizes, two bloom sizes and four sizes of rounds. As demand increased and the product range extended, caster productivity, casting speeds and product quality did not meet the necessary standards needed. Lechler assessed the secondary cooling system and designed and installed an air-mist system to replace the existing water-only system for the beam blank sizes. Significant gains in productivity and quality have been achieved. The strands will now be converted for use with blooms and rounds.

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The 4-strand combi caster at SMS-II of Jindal Steel & Power Ltd (JSPL), Raigarh, commissioned by Siemens VAI in 2003, was designed to produce two beam blank section sizes, two bloom sizes and four sizes of rounds. Steel grades included low and medium carbon, peritectic and microalloyed grades. The caster is fed by 100t ladles in a ladle turret via a 27t tundish. The steel is processed through a submerged entry nozzle into an 800mm long curved mould, which is equipped with an electromagnetic stirrer. The casting radius is 12m and the strand support is provided by 3 segments. The machine had 5 secondary cooling zones fitted with water-only nozzles.

Because of the range of product sizes cast, multiple segments are exchanged with the change of format and section sizes. Both beam blank section sizes have different foot rollers as well as different designs for segments 1 and 2, whereas segment 3 design is identical for all beam blank and round formats. The continuous straightener has 4 rolls and the strand is cut with a torch cutter after a machine length of 38.8m.

Maximum casting speeds were limited to 0.76 and 1.10m/min for casting large and small section beam blanks respectively, but despite this, typical quality problems in casting beam blanks, such as surface cracks in the web region were observed.

Beam blank format (w x h x flange t) (mm)	Max. casting speed (m/ min)
355 x 280 x 90	1.1
480 x 420 x 120	0.76

Table 1 **Max. casting speeds before conversion**

Over time, the product range has widened as a result of the growing market for long products, leading to the need for higher productivity, combined with a greater flexibility and an improved product quality and resulting in the project described below.

CASTING DATA BEFORE CONVERSION

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 1*.

Local overcooling as a result of nozzle clogging, poor nozzle alignment and uneven cooling were causing deformations of the flange side. The subsequent flange side concavity was also a major quality issue. In addition, the secondary cooling was suspected as a cause for frequent breakouts which further reduced the productivity of the caster.

The water-only nozzles were frequently clogged which amplified the uneven secondary cooling and the related problems. Nozzle clogging also led to extensive maintenance because of frequent nozzle changes.

Another issue which is typical of beam blank casters was the amount of running water on the loose web side of the beam blank. This frequently caused overcooling of the web face and hence promoted the formation of longitudinal surface cracks (see *Figure 1*).

CASTER UPGRADE

As part of the project to improve productivity and quality, a secondary cooling study was conducted on all section

Fig 1 **Web surface cracks on beam blank**

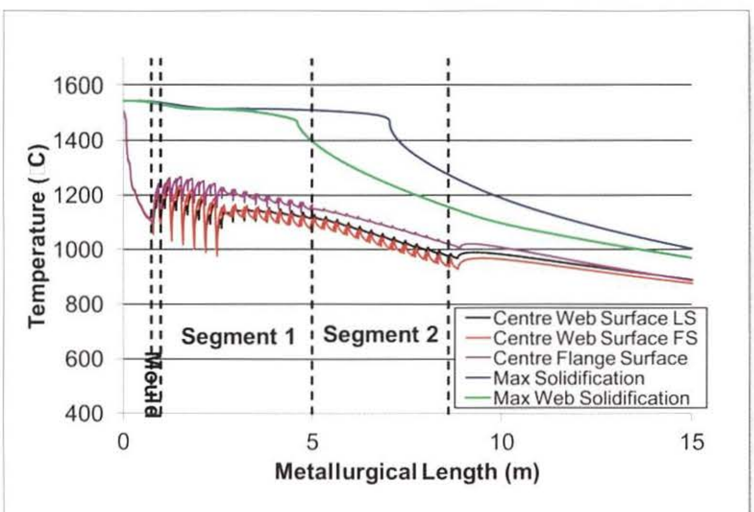

Fig 2 **Solidification profile of C18 grade for small beam blank at 1.1m/min before conversion**

sizes to determine the potential benefits of a conversion to an air-mist secondary cooling system. The main objectives were to increase current casting speeds to the original 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 in February 2014.

Process optimisation In order to increase the caster productivity and improve the product quality, the casting and solidification process was simulated. Existing conditions providing good quality were used as a benchmark for the optimisation of the secondary cooling process.

For this exercise, the caster geometry and process data was collected and used in a finite difference model (FDM) for the simulation of the solidification process. The caster geometry included mould length, roll positions on all sides and straightening configuration. Process data consisted of casting speed, superheat temperature, meniscus level, mould cooling data and secondary cooling data.

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

During a plant visit the simulated bloom surface temperatures on all faces were verified with pyrometer measurements. Based on these results an optimised secondary cooling system was designed to maintain good quality at increased speeds and productivity. The water supply was to remain as existing, but for segments 1 and 2 an additional air supply was required.

The nozzle layout was modernised by installing air-mist nozzles of Lechler Mastercooler and Billetcooler type in segments 1 and 2. By using 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 air-mist cooling zones at a constant air supply pressure of 2 bar.

The casting speeds could be significantly increased over the previous system while maintaining similar solidification profiles. The recommended casting speeds with the new secondary cooling design are shown in *Table 2*.

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 sides are increased as a result of the casting speed increase. Even though the final solidification on both sides takes place

Beam blank format (w x h x flange t) (mm))	Max casting speed (m/ min)
355 x 280 x 90	1.5
480 x 420 x 120	1.1

Table 2 **Proposed maximum casting speeds after conversion**

Segment	Zone	Nozzle type
Ring	1	Water only
1	2	Master cooler
	3	Billet cooler
2	4	Billet cooler

Table 3 **New nozzle layout for beam blank caster**

shortly after the end of support the shell thickness is sufficient to reduce bulging to an acceptable level.

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, matching the new requirements.

A new air valve skid shown in *Figure 5* was installed to provide air supply and control of the air-mist cooling zones. The air pressure can be individually controlled for each cooling zone. Also individual strainers have been installed in each air line to provide optimum air quality.

Headers for the new nozzle layout shown in *Table 3* were engineered and designed, providing a maintenance-friendly and wear resistant design to meet high quality standards.

The Mastercooler nozzles were especially designed to match the process requirements. Extensive measurements of liquid distribution for all required operating conditions were carried out and new spray plans have been provided which define 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 has been updated with the additional pipes and instrumentation. A commissioning manual has been created listing all required checks before casting and a process manual supplied summarising 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.

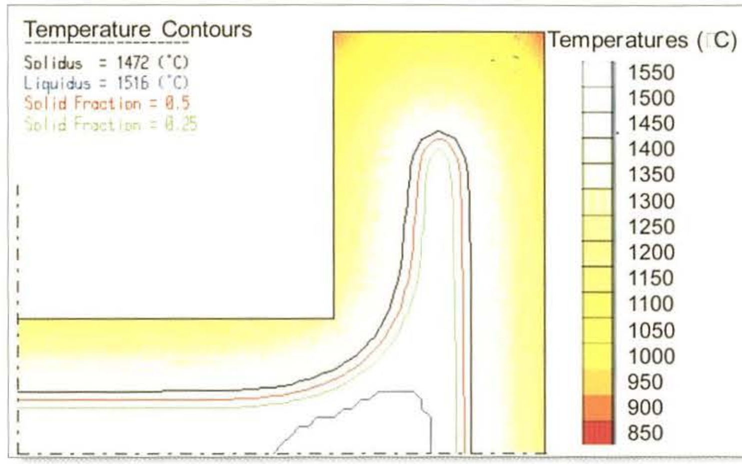

Fig 3 **Existing temperature profile of simplified beam blank geometry quarter cross section at 2m below meniscus of C18 grade for small beam blank at 1.1m/min**

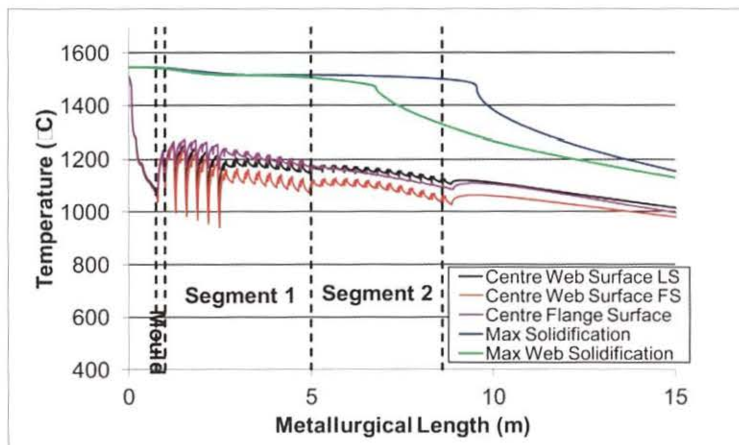

Fig 4 **Solidification profile of C18 grade for small beam blank at 1.5m/min after conversion**

Fig 5 **New Air valve skid for air supply of segments 1 and 2**

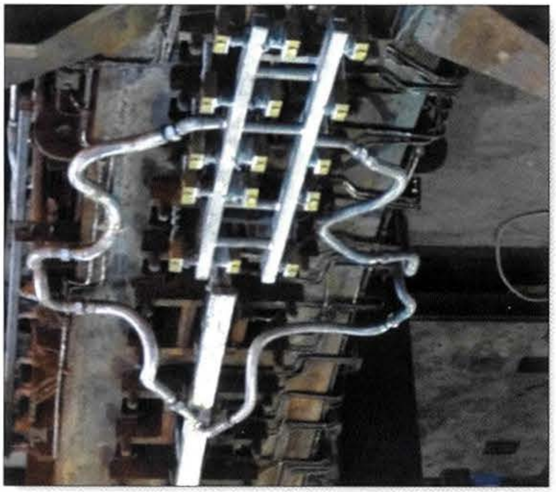

Fig 6 **Segments 1 & 2 with new air-mist headers mounted on strand 1 during cold commissioning**

Section	Max. 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

Table 4 **Proposed maximum casting speeds before and after conversion for all section sizes**

New control software was supplied and the additional controls for the new instrumentation for air supply was 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 was 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 systems were successfully cold commissioned, including functionality checks of all old and new instrumentation. The new software was 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 were conducted.

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

Fig 7 **Top view on straightener during hot commissioning of strand 1 (right)**

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 of the straightener during hot commissioning. Strand #1 on the right side of the picture has been converted to air-mist cooling while the other strands were still operating with the old system. Clearly the elevated surface temperature can be seen.

First surface inspection after hot commission indicated an improved quality of the converted strand #1. There were no indications of flange face deformations and the web surface cracking was reduced to a minimum. After successful hot commissioning of 1 strand for small and big beam blanks, all strands have been subsequently converted. The initial observation was verified and confirmed during the first year of operation. The results for longitudinal cracking are shown in *Figure 8* for all strands indicate an average cracking reduction from 3.4% before the conversion to 1.2% with the new air-mist cooling system.

The amount of running water on the beam blank fixed web side was also significantly lowered, so reducing overcooling and hence reducing thermal strains of the material.

The problem of breakouts has been virtually eliminated

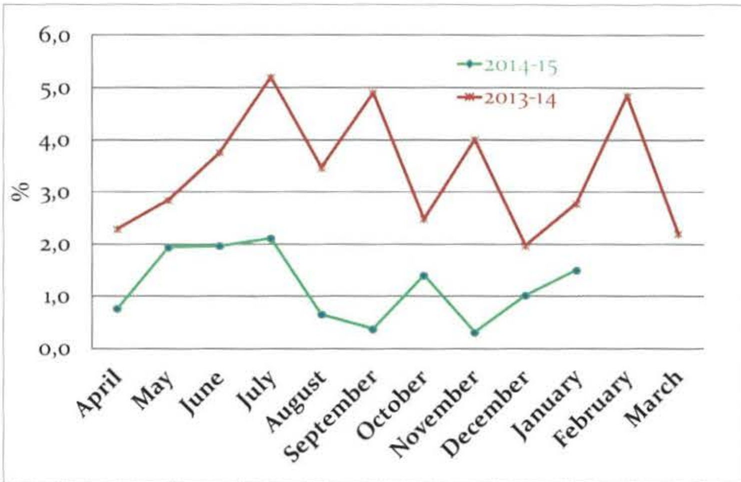

Fig 8 **Comparison of longitudinal cracking before (red) and after (green) conversion**

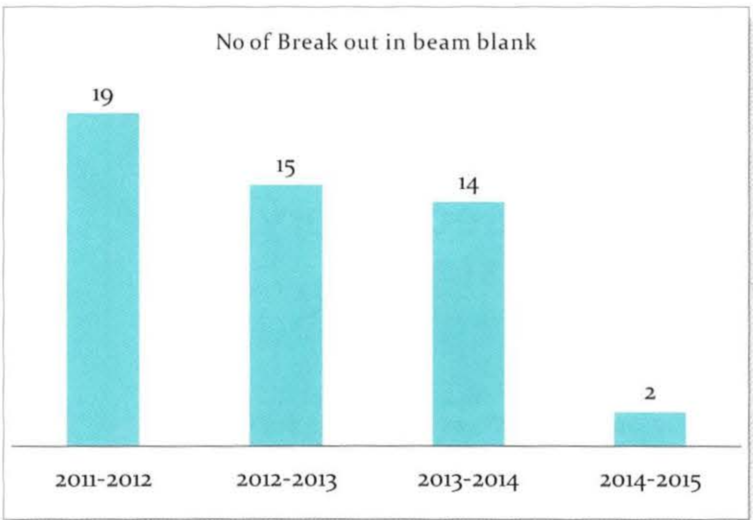

Fig 9 **Number of breakouts before (2011-2014) and after (2014-15) conversion. All strands**

after the conversion with no breakouts occurring which can be attributed to the optimised secondary cooling (see *Figure 9*). Significantly reduced maintenance costs and the increased productivity of the caster are the other two objectives which have been met.

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

Nozzle clogging issues have been 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 speed for all section sizes is shown in *Table 4*. The increase in productivity will be even higher since an improvement in product quality combined with a reduction in shut down time are also expected.

CONCLUSIONS

1. The secondary cooling system of one strand of a 4-strand combi caster at SMS-II of Jindal Steel & Power Ltd has been converted from water only to air-mist with the aim of improving caster productivity, cast product quality and operating cost.

2. As a result, caster productivity has significantly increased, resulting both from a 15 to 20% increase in casting speed and a reduction in cooling-related breakouts from 16 per year to nil. Spray nozzle clogging has been eliminated.

3. As a result of these improvements, plans are being developed to convert the remaining bloom and round sections and also to convert caster number 3 to a similar secondary cooling system.

DEFINITIONS (FIGURES 2 AND 4)

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

Max Web Solidification: *Point of final solidification on web side.* MS

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