Consequent secondary cooling system optimization results in productivity increase at TATA Steel Jamshedpur LD2 slab casters

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Summary
Tata Steel Jamshedpur LD2 are operating 3 slab casters which have been revamped in 2005 to achieve design maximum casting speeds of 1.8 and 1.75 m/min respectively. These speeds could not be achieved until recently due to bulging and related mould level fluctuation. A section thickness increase further aggravated this issue.
From 2012 several investigations have been conducted in order to improve the process including a secondary cooling study performed by Lechler. As a result of these investigations the secondary cooling layout has been optimized in several steps, each improving the quality of the products and the productivity of the casters. These steps included redistribution of existing cooling water capacities, utilization of additional secondary cooling water capacities, revision of the secondary cooling intensity, revamp of secondary cooling nozzle and header design and extension of the secondary cooling length.
After implementing all steps an increase of 20 % in maximum casting speed could be achieved, the secondary cooling intensity was increased from 0.9 l/kg to 1.7 l/kg. The problem of bulging and mold level fluctuation have been eliminated.

These measures are giving a boost to the productivity and could be realized within regular maintenance time with minimum capital invest (CAPEX).

Key Words
Continuous Casting, Secondary Cooling, Productivity Increase, Bulging

Background
The 3 slab casters at Tata Jamshedpur LD2 are among few casters, which run with specific secondary cooling spray water intensity of less than 1 l/kg of steel. A general comparison of this value to other machines is rather difficult as caster and product dimensions are varying as well as steel grades. However l/kg is universally accepted measure to benchmark slab cooling water among casters having different designs as depicted in Figure 1.

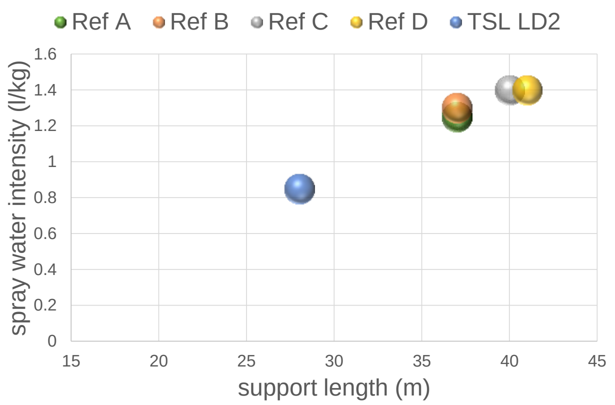

Figure 1: Water benchmarking of different slab caster using spray water intensity (l/kg)

In order to achieve a similar spray water intensity compared to reference plants, LD2 casters capacity requires an enhancement by approx. 60 %. The low secondary cooling water availability at casters often results in slab bulging once casters run at high casting speed or imposes speed restriction due to inter roll bulging.

All three casters were upgraded in 2005 to attain a speed of 1.8 m/min (CCM1) and 1.75 m/min (CCM2&3) for 210 mm slab thickness, however those speeds had never been achieved even during performance guarantee test.
Until 2012, the maximum casting speed was restricted to 1.5 m/min due to inter-roll bulging related mold level fluctuation.

The primary reason of inter-roll bulging was identified as low secondary cooling water availability and high roll gap in the upper cooling zones. This problem aggravated after slab thickness increase to 215 mm.

Initial improvements
A bundle of intermediate measures has been implemented in order to reduce the bulging and mold level hunting problems.

1) 3x3 water pump operation (2012-13)
It was observed that, at high speed casting (when water requirement is on higher side), the water line pressure loss increases significantly which results in

unachievable set flow rates. In order to achieve the set flow rates by increasing the main line pressure it was decided to have all 3 pumps operational simultaneously and install a 4th pump as stand by.

2) Interconnection of water line (2012-13)
This modification was based on the fundamental assumption that generally all casters do not have simultaneous peak load of water requirement.
For the typical product mix of LD2, often one caster runs with Peritectic or IF (low water requirement) grades, so additional water of such casters may be diverted to the other casters running at high speed.
The secondary cooling water circuits of CCM1-CCM3 were interconnected to achieve optimum utilization of available spray water capacities as per need of the casters.

3) Increase of spray water intensity at upper cooling zones (2015)
A secondary cooling system study of LD2 conducted by Lechler indicated substantial slab bulging strain in the upper cooling zones. A comparison of the bulging level at the maximum speed with acceptable quality (1.6 m/min) and aim speed of 1.85 m/min is shown in Figure 2.

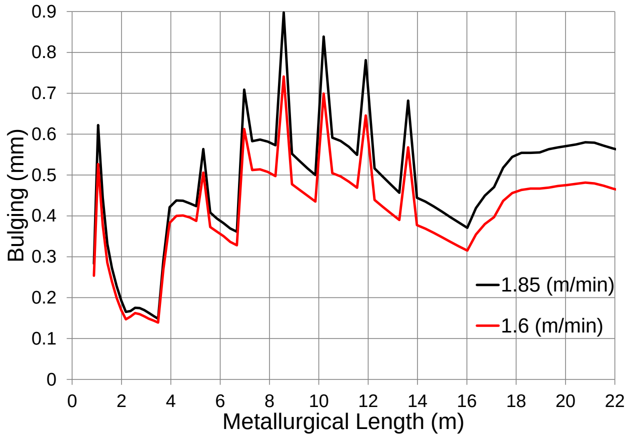

Figure 2: Simulation of bulging strain at different length for varying casting speed

As a result, an in-house project was initiated to enhance the secondary cooling water supply in the upper zones (z0, z1A, z1B and z2) by changing configuration/rating of nozzles. The resulting zone flow rate increase is shown in Figure 3.

The combined initial improvements resulted in an increase of the main header pressure of approx. 10%, the upper cooling zone flow rates could be increased by 10-30 %. This helped to reduce the bulging levels, related quality problems and to achieve a consistent casting speed of 1.65 m/min on CCM2&3 and 1.6 m/min on CCM1 respectively.

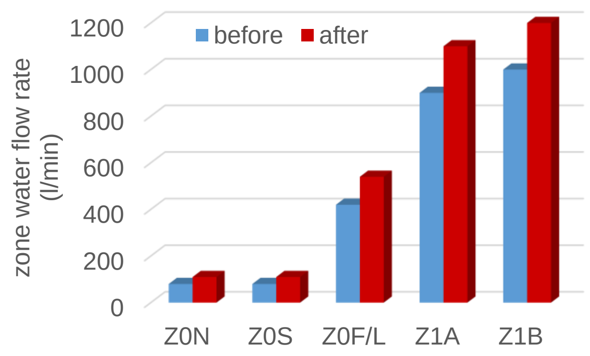

Figure 3: Increase in zone water flow rate in upper zone after nozzle change

However the increased water flow rate also increased line pressure losses and the main line pressure was reduced again to 8-10 bar.

Study of secondary cooling system

Lechler was tasked to further investigate the existing secondary cooling system and advise on measures required to achieve a maximum casting speed of 1.85 m/min.

Based on the benchmarked temperature, solidification and strain results for existing conditions with acceptable quality, a further optimization of the secondary cooling system has been proposed in order to achieve the same or improved quality at increased target speed.

The mayor modifications to achieve the target speed were:

- redistributing and increasing the secondary cooling spray water
- increasing the secondary cooling length
- optimizing the nozzle layout

A comparison of the existing surface temperature profile at a casting speed of 1.6 m/min and the proposed profile at an increased speed of 1.9 m/min are shown in Figure 4.

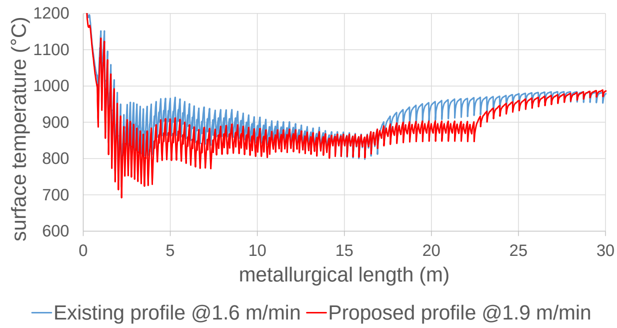

Figure 4: comparison of existing and proposed surface temperature profile for LC grade

As a result of the modified cooling strategy the surface temperature of the proposed profile is reduced in the upper cooling zones even as the casting speed is increased. However, due to the optimized nozzle design the surface temperature fluctuation could be reduced at the same time. The extended secondary cooling length reduces the surface reheat before final solidification.

The comparison of the bulging levels at the maximum casting speed of 1.6 m/min with the achievable levels at increased casting speed of 1.9 m/min is shown in Figure 5.

Figure 5 shows the comparison of the bulging levels between the existing secondary cooling system at maximum casting speed (red line) and the proposed layout at new target speed (blue line).

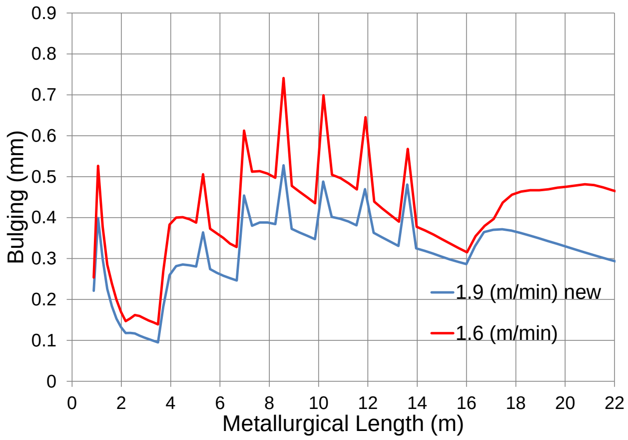

Figure 5: Simulation of bulging strain at different length for existing and proposed layout at maximum speed

A reduction of bulging levels even at the target maximum casting speed is calculated at all positions by 20-30 %, which will also reduce mold level fluctuation. The increased secondary cooling length reduces the bulging increase before final solidification.

According to these promising results the optimized secondary cooling nozzle layout was proposed for implementation.

The Project

The secondary cooling study results by Lechler have also been confirmed by other companies. Therefore, a complete upgrade of the secondary system, including an increase of the cooling water capacity by 70 %, was proposed in order to achieve a maximum casting speed of 1.85 m/min with consistent slab quality.

The existing casters secondary cooling system is divided in six zones. Cooling zones 1-5 cover segment 1-8 and are responsible for direct secondary cooling. Zone 6 is mainly dedicated to roll and machine cooling.

One recommendation derived from the study was the extension of the direct secondary cooling system until the end of strand support which will increase the secondary cooling length by max. 16 m.
However, the main result of the study was the requirement of increased secondary cooling spray water supply which offers 2 additional advantages:

1) An increase in secondary cooling water capacity may be utilized for slab cooling from segment 9 to segment 15 (extended cooling).

2) An increase in secondary cooling water capacity may be utilized to eliminate flume flush and granulation problems.

Increasing the secondary cooling water capacity

It was possible to immediately raise the operating water pressure resulting in higher water flow rates to the existing segments without any physical modification. During DOE, an increase of 10 % in pressure lead to 5 % increase in flow rate (Table 1).

Zone	Increase in pressure (%)	Increase in flow rate (%)
0N	10	5.1
0S	10	3.8
1A	10	6.2
1B	10	6.6
2	10	6.2
3	10	6.5
4I	10	5.8
4O	10	5.7
5I	10	4.4
5O	10	4.8

Table 1: Pressure vs. flow rate change in different cooling zones

In the initial configuration of the casters, ~8000 l/min were supplied by the water plant to each caster. Out of the available water flow rate, ~4400 l/min are distributed to slab cooling and ~3600 l/min is utilized for flume flushing, TCM granulation and scale flushing.

Different water qualities are required in the secondary cooling circuit and the flushing circuit. Whereas the slab cooling circuit requires clean, chemically treated and cold water, the flush circuit requires pressurized water only. No detrimental effect on the flush system is expected if the water is slightly dirty and hot. Therefore, an isolation of the flush/granulation circuit from the secondary cooling water was planned, increasing the capacity to 8000 l/min.
The isolated flushing line will be fed from a separate pump from the existing scale pit.

The conversion job was planned and executed during normal monthly shutdown without additional downtime. The job was executed and completed with the help of Tata Steel employees and regular contract persons only.

The Result

The secondary cooling conversion was successfully conducted in autumn 2018 and the target casting speed of 1.85 m/min has been consistently achieved giving a mayor boost to the productivity.

After the successful conversion of CCM2, also CCM1&3 will be converted accordingly.

Established benefits from secondary cooling conversion:

1) An increase in caster water availability by 80% by optimized cooling water capacity utilization. The current modification eliminate upgradation requirement at main water plant supply circuits and hence will reduce scheme cost by at least 70%.

2) The extended secondary cooling length helped in reducing the center line segregation problem.

3) A maximum casting speed of 1.85 m/min has been achieved with improved slab quality which represents a total increase of 20%.

4) Excessive slab bulging and mold level fluctuation has been eliminated (see reference Figure 6).

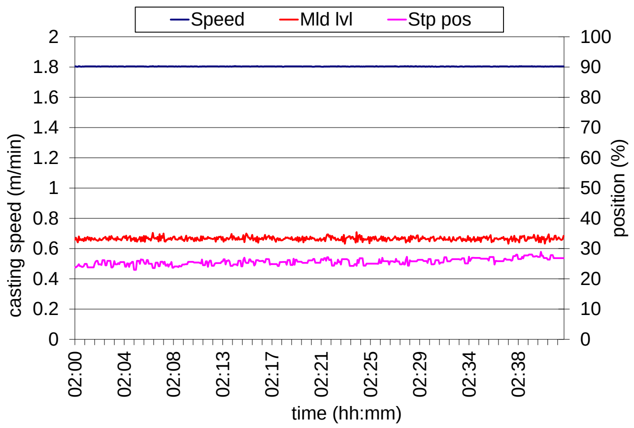

Figure 6: Mold level stability example at casting speed of 1.8 m/min

5) The optimized caster is achieving a 15 % higher production in comparison to the other two unmodified casters. Total production impact +0.15 MTPA/caster

6) A final conclusion about the increase of the productivity will be established after 12 month of continuous operation with the new secondary cooling system.

Conclusion

The implementation of the recommendations of the secondary cooling study by Lechler resulted in an increase of 20 % in maximum casting speed, the secondary cooling intensity was increased from 0.9 l/kg to 1.7 l/kg. Quality problems such as bulging and mold level fluctuation have been eliminated. The implementation could be realized within regular maintenance time. This resulted in a boost to productivity with minimum capital invest.

Abbreviations

CCM – continuous casting machine
l/kg – liter per kg derived from secondary cooling water flow rate, casting speed, slab dimensions and steel density
DOE – design of experiments