Upgrading of CC2 bloom caster at RINL Visakhapatnam steel plant

Significant upgrading of No.2 caster at RINL Visakhapatnam steel plant increased production by 66%, improved both internal and external quality of the cast blooms which are used for a wide range of structural, free cutting, engineering and wire grades.

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Visakhapatnam Steel Plant and Tata Steel Engineering

The Visakhapatnam Steel Plant (VSP) of Rashtriya Ispat Nigam Limited (RINL) in Andhra Pradesh, India, has six bloom casters, each having four strands producing 250 x 250mm and 250 x 320mm blooms.

It was decided to upgrade certain critical aspects of the No. 2 caster in order to achieve the following objectives:
- Greater throughput capability (1Mt/y) and higher plant availability
- Enhanced production of higher quality and value-added steels
- Auto mould level operation to overcome manual operation-related problems

The main areas to upgrade were identified by VSP as follows:
- New and automated tundish stopper and argon purge systems
- New moulds and allied facilities
- Mould electro-magnetic stirrers (MEMS)
- Automatic mould level measuring and control system (AMLC)
- New mould oscillator tables
- New mould foot roller assemblies and zero segment assemblies, together with enhancements to segment N1 and associated spray zones
- Appropriate alignment, testing stands and gauges
- Central grease lubrication system
- New mould cast floor panels, mould cover plates and renewal of spray chamber walls and steam exhaust fans
- Integrated alignment of the whole machine (new items to existing)
- Renewal of the electrical power and process control systems, including DC to AC drive conversion and complete renewal of SCADA/PLC/drive equipment
- Renewal of water distribution, monitoring and control systems local to the caster
- Associated operation and maintenance training

After undertaking an extensive study and selection process VSP arranged for the caster upgrade to be led by Tata Steel Process Engineering (TSPE), a company that has designed and supplied casting plants for more than 50 years from its base in Workington, UK.

STEEL GRADES
The steel grades designed into the upgrade are given in Table 1.
UPGRADE DETAILS

Mould level and tundish outflow control
To achieve improved and consistent bloom surface quality the tundish to mould flow control system has been automated by means of level detection and electric stopper actuation, supplemented by automatic argon gas delivery systems (see Figure 1). A water-cooled radioactive level detector is located at each mould table with a corresponding ‘pencil’ type source located vertically behind the mould inner radius copper plate. While the actual metal level is important, it is minimisation of the rate of change of level that is the main factor governing product surface quality.

Mould
New moulds were provided that differed from the original ones as follows:

- Copper plate tapers were optimised into a single taper for the product range.
- Internal cooling was improved by means of a special mould geometry design to allow a 50% increase in casting speed while maintaining a strong uniform shell thickness at mould exit.
- Mould material was improved by using special copper alloy having greater hardness and higher hot strength and softening temperature together with the application of a hot face electroplated chrome coating.
- Internally located level detection device and source were incorporated into the new mould assembly.
- Pre-alignment of the copper plate sub assembly to Back of Mould Datum and Right Hand Side Datum is done within workshop setting stands and removes the need for further adjustments at the caster – giving faster mould exchange time.

Table 1 – Steel grade notes
1 Single values within the table are maximums unless otherwise indicated.
2 Residual aluminium typically 0.005-0.007%.
3 No Ca treatment
4 Steels are grouped according to use as follows:
   a Low and medium C including corrosion-resistant grades being used for rolling of bulk structural elements such as beams, channels, angles and bars
   b High C grades being used for bars and wires
   c Spring steel grades
   d Free cutting including case hardening grades for manufacture of large quantity engineering components
   e Forging, engineering and case hardening grades for manufacture of more critically loaded engineered components.

Table 1 Steel grade mix

<table>
<thead>
<tr>
<th>VSP Grade</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Cr</th>
<th>Cu</th>
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<tr>
<td>EQ</td>
<td>0.08</td>
<td>0.40/0.52</td>
<td>0.025</td>
<td>0.025</td>
<td>0.030</td>
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<td></td>
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<tr>
<td>1008</td>
<td>0.07</td>
<td>0.30/0.45</td>
<td>0.040</td>
<td>0.040</td>
<td>0.30</td>
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<tr>
<td>CRM</td>
<td>0.20</td>
<td>0.80/1.10</td>
<td>0.045 min</td>
<td>0.04</td>
<td>0.15/0.35</td>
<td>0.40/0.65</td>
<td>0.20/0.30</td>
</tr>
<tr>
<td>CRA</td>
<td>0.20</td>
<td>0.80/1.10</td>
<td>0.045 min</td>
<td>0.04</td>
<td>0.15/0.35</td>
<td>0.20/0.45</td>
<td>0.20/0.30</td>
</tr>
<tr>
<td>PRG</td>
<td>0.20/0.25</td>
<td>0.50/0.90</td>
<td>0.05</td>
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<td>0.35</td>
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<tr>
<td>Fe500</td>
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<td>0.75/1.20</td>
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<td>0.05</td>
<td>0.35</td>
<td></td>
<td></td>
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<td>En15</td>
<td>0.30/0.40</td>
<td>1.30/1.70</td>
<td>0.05</td>
<td>0.05</td>
<td>0.15/0.35</td>
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<tr>
<td>20MnCr5</td>
<td>0.17/0.22</td>
<td>1.10/1.40</td>
<td>0.035</td>
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<td>0.15/0.40</td>
<td>1.00/1.30</td>
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<tr>
<td>37C15</td>
<td>0.32/0.42</td>
<td>1.30/1.70</td>
<td>0.035</td>
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<td>0.15/0.35</td>
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<td>1541</td>
<td>0.36/0.44</td>
<td>1.35/1.65</td>
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<td>0.15/0.35</td>
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<tr>
<td>EN8D</td>
<td>0.40/0.44</td>
<td>0.70/0.90</td>
<td>0.04</td>
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<td>0.05/0.35</td>
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<td>SUP9</td>
<td>0.52/0.60</td>
<td>0.65/0.95</td>
<td>0.035</td>
<td>0.035</td>
<td>0.35</td>
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<tr>
<td>HC65</td>
<td>0.61/0.64</td>
<td>0.50/0.80</td>
<td>0.03</td>
<td>0.03</td>
<td>0.15/0.30</td>
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<td>HC75</td>
<td>0.71/0.74</td>
<td>0.50/0.80</td>
<td>0.03</td>
<td>0.03</td>
<td>0.15/0.35</td>
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<td>HCB0</td>
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<td>0.50/0.80</td>
<td>0.03</td>
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<td>0.15/0.30</td>
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<tr>
<td>HCB5</td>
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<td>0.50/0.80</td>
<td>0.03</td>
<td>0.03</td>
<td>0.15/0.30</td>
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<tr>
<td>55Si7</td>
<td>0.50/0.60</td>
<td>0.80/1.00</td>
<td>0.04</td>
<td>0.04</td>
<td>1.50/2.00</td>
<td></td>
<td></td>
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<tr>
<td>1524Cr</td>
<td>0.23/0.28</td>
<td>1.35/1.65</td>
<td>0.04</td>
<td>0.04</td>
<td>0.15/0.35</td>
<td>0.20/0.30</td>
<td></td>
</tr>
</tbody>
</table>

Fig 3 New mould table and old support frame
Robust design to resist in-service thermal and mechanical forces and maintain dimensional accuracy

**Mould oscillating tables** The original mould tables suffered from geometrical instability and some dynamic imbalance. Therefore new more robust and stable tables were provided to improve dynamic stability. The tables were attached to modified existing ground frames and provided with new water and auto lubrication services.

One of the more difficult tasks during installation was the determination of main caster benchmarks such as Back of Mould Datum line, strand centrelines and the absolute height benchmarks – none of which were readily available. Joining together of new and old components presented a further difficulty. Fortunately, TSPE has had a great deal of experience undertaking this type of work on older Tata Steel casters in the UK, which have been progressively upgraded since the 1990s so that this know-how (especially detail design, pre-shutdown preparations and site working) could be employed effectively at VSP (see Figure 3).

The original fixed stroke eccentric oscillator assembly was changed to a new adjustable type. To minimise caster shutdown time the original oscillation assembly ground frames were retained and adapted to be reused by the new drive train equipment (see Figure 4).

**Zero segment and foot rolls** Completely new zero segment assemblies were provided along with non-magnetic foot roller sub-assemblies. Tata Steel Research Development & Technology group (RD&T) created a thermal model of the new caster containment and undertook spray cooling thermal modelling. This work identified the roll pitching and spray zone water intensities specific to the section sizes, family of steel grades and intended casting speeds.

Roll pitching and spray nozzle selection is a balance between the theoretically desirable and what is practically achievable. For example, it is well known that close roll pitches will reduce inter-roll bulging and provide improved product support. However, as rolls are moved closer together, if they are misaligned, product strains are increased. Therefore, any roll geometry has to be a compromise between minimisation of product strains caused by inter-roll bulge and that caused by roll misalignment.

**OTHER PRODUCT CONTAINMENT ASPECTS**

- Physically different nozzle fixings for each spray zone to prevent incorrect fitting of nozzles
- Roll support shafts with independent eccentric shaft adjustment or packing at each end
- Rolling element bearings within rolls in the harshest environment (closest to the mould)
- Plastic bushes used for rollers further away from the mould, found to be more cost-effective than self-lubricating metals
Segment set up, water testing and alignment complete with the mould is achieved in the workshop – removing the need for extensive work at the caster.

In view of the harsh environment immediately beneath the mould, the foot roll assemblies are detachable from the main body of the zero segment and have rolling element bearings in fully lubricated and sealed housings. In addition, the rollers are made from special non-magnetic hard stainless steel and many of the other component parts of their sub-assembly are also non-magnetic in order to maximise the penetration of EMS flux into the bloom and minimise power consumption (see Figure 5).

MEMS Rotary stirring motion EMS units are statically mounted and automatically located on top of the zero segments. The mould assemblies auto locate onto the mould table and are oscillated with their lower portions inside of the circular EMS coils (see Figures 6 & 7).

To exchange the zero segment the mould is first removed and the EMS coil is simply lifted carefully from the top of the segment onto the adjacent strand floor plate without the need for any disconnections.

The stirring coils are cooled by their own water re-circulating system and powered via new electrical systems incorporating HV switchgear, operating and standby transformers, coil drive panels and local connecting and hydro-electric monitoring units. Stirring frequency and intensity is predetermined according to previous experiences of Tata Steel and the EMS supplier.

The main reasons for using such systems were:
- Increase in equiaxed structure within the cast product
- Minimisation of chemical segregation throughout the cross section, especially in the central region
- Minimisation of subsurface pinholes and centre porosity

Electrical power and control systems The entire existing caster motor control centres were replaced with modern technology. The drives of the main strand pinch rollers, dummy bar winches and mould oscillators were converted from DC to variable voltage and frequency AC drives (see Figure 8).

Completely new PLC and HMI systems were provided to allow better, more automated control of the caster and importantly to allow data logging of casting parameters, alarms, etc.

Water systems The mould and spray cooling water flow monitoring and control systems local to the caster were completely replaced. Modular off-site construction was employed to reduce working time at this location, which was extremely hot and dry because of ongoing casting operations.
on the adjacent casters (see Figures 9 & 10). The upgrading also included local mould and spray water pressure boosting pumps as well as auto self-cleaning filters to service the new requirements.

**RESULTS**

Following recommissioning these main benefits have been realised:

- Casting rates have been increased by ~50% (from 0.7-0.9 m to 1.2-1.4 m/min) and the caster ladle drain time is now matching converter metal supply capability, leading to more secure ladle sequence scheduling, longer sequences and less time spent waiting for steel.
- Annual production rate has increased from ~0.6 to 1 Mt/y.
- Improvements in subsurface and internal quality by means of application of MEMS and auto level systems (see Table 2).
- Improvements in surface quality and consistency by means of high stability mould oscillation tables and automatic mould level control.
- Reductions in breakout frequency from two to three per month per machine to less than one per month per machine due to higher automation levels (less operator variability) and increased mould thermal efficiency.
- Improved bloom shape (see Table 3).
- Higher plant operational availability.
- Increased life of casting assemblies such as moulds and zero segments (typically from 250 heats up to 750).
- Modernised and future-proofed electrical power and control systems, water services and mechanical plant facilities.
- Cultural changes in operation and maintenance teams.

Mould plate service life between re-machining increased by a factor of three to ~25 kt for new coated plates and by a factor of two to ~16 kt for uncoated plates (see Figure 13).

**People** Without the support dedication and commitment of people no upgrade can succeed. This was recognised by the
managers of VSP and they paid great attention to training before and during caster shutdown. Good cooperation of caster operators with maintenance personnel led to the development of a common team spirit that facilitated knowledge sharing and learning from one another. Small task teams were formed to overcome difficulties and a real sense of pride was engendered within the caster operations workforce. The importance of this aspect to the project cannot be overemphasised.

CONCLUSIONS

By selective upgrading of the machine, the objectives of quality and productivity improvements have been achieved and manual operations considerably eliminated.

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