HIGH-QUALITY HOT STRIP PRODUCTION
from thin slabs at Essar Steel in India
In 2010 and 2011, Essar Steel India extended its production capacity at the Hazira steel works by 5 million t/year of crude steel and another 3.5 million t/year of hot rolled strip. The pertaining plant technology consists of two 200 t Conarc® furnaces, three twin-ladle furnaces and a CSP® plant. Whereas the latter started operating with two strands, it has meanwhile been extended to become the world’s first three-strand CSP® plant. This article describes the plant technology and presents the most important operating results in the commissioning phase.

Watch a video of this steel plant using your smartphone and this QR code linking to: www.sms-siemag.com/qr/essar_csp/

Figure 1. Layout of the three-strand CSP® plant.
Essar Steel India is one of India’s largest producers of flat steel products intended to be used, for example, in the automotive, construction and shipbuilding industries. In 2007, the company placed an order with SMS Siemag for the supply of a steelworks comprising two 200 t Conarc® furnaces and three twin-ladle furnaces. With this new steelmaking plant, crude steel capacity at the Hazira location has been increased to a total of 10 million t/year.

The new Conarc® furnaces are designed for a capacity of 5 million t/year. The major part of the steel is intended for the new thin-slab casting and rolling (CSP®) plant, figure 1, which is designed for the production of 3.5 million t/year of hot strip. A further part is processed in the conventional continuous slab caster.

**STEELMAKING PLANT**

Whereas the two EAFs represent the heart of the meltshop, three adjacent twin-ladle furnaces are used for refining. The Conarc® EAF process is a combination of the traditional routes of oxygen and electric arc furnace steelmaking. The technology consists of a twin-shell furnace, using a slewable set of electrodes as well as at least one slewable top lance, which are alternately used in both shells, figure 2.

This equipment provides for high flexibility in terms of charge materials. The furnaces can process hot metal, pig iron, DRI and scrap. The choice of input material can be dynamically adapted to fluctuating market prices of energy and raw materials.
At the ladle furnaces, temperatures and alloy addition can be precisely adjusted. Using a ladle furnace, offers significant advantages for meltshop operation. These include:

- improved ladle logistics when feeding liquid steel to the continuous casters,
- improved steel quality and desulphurization capacity,
- low emissions (particle, GHG, noise etc.),
- low electrode consumption,
- low consumption of alloying agents.

An off-gas treatment plant is used for dedusting and cleaning the primary and secondary off-gases. The whole steelmaking plant is controlled and monitored by an X-Pact® level 2 automation system with the pertaining metallurgical process models. Quality data and production data are visualized on the HMI, enabling simple and intuitive interaction.

**THIN SLAB CASTING AND ROLLING PLANT**

The CSP® thin slab casting and rolling plant produces hot strips in widths from 950 to 1,680 mm and in thicknesses between 1.0 and 25.0 mm. Two CSP® continuous thin slab casters were started up in 2011, providing an annual capacity of 2.5 million t of hot strip. In the future, this mill will be extended by a third continuous casting machine to become the world’s first three-strand CSP® plant with a total capacity of 3.5 million t/year.

Essar Steel India is using the innovative CSP® technology specifically for the production of high-quality steel grades. Besides low, medium and high-carbon steels, also tube steels, silicon steels and dual-phase steels can be produced in high quality.
By subsequent casting and – after passing the furnace – immediate rolling of the slabs, the CSP® technology is particularly energy-saving. The technical data of the plant are summarized in Table 1. The main equipment of the mill comprises:
- tunnel furnaces with swivel ferry,
- seven finishing stands,
- CVC® plus with work-roll shifting and bending system,
- hydraulic adjustment systems,
- hydraulic and differential tension loopers,
- two downcoilers,
- complete X-Pact® electrical and automation systems.

**Figure 1** shows the layout of the three-strand plant.

**Continuous casting machines.** The CSP® casters, figure 3, are vertical solid bending type machines consisting of four segments each. The metallurgical length is 8,065 mm. The process engineering allows a stable and precisely controlled production sequence. The mold monitoring system recognizes malfunctions at an early stage and hence prevents break-outs. For systematic cooling of the strand, the dynamic solidification control tool calculates the solidification parameters and specifies the necessary settings for the cooling water.

Liquid core reduction technology (LCR3) enables the slab thickness to be infinitely set within a range from 55 to 80 mm. To reduce the strand thickness, the segments taper along the metallurgical length. LCR3 technology incorporates casting speed adjustment and provides the optimal input thickness for the rolling mill. The mold level control system contributes to enhanced product quality and maximized throughput.

**Furnaces.** Fuelled with natural gas or process gas, the CSP® furnaces ensure an entirely homogeneous temperature distribution within the thin slab. During work roll changing in the rolling mill, the tunnel furnace buffers slabs for the casters to continue operating. The rear parts of the furnaces can swivel like ferries, flexibly connecting the two outside strands with the centreline towards the rolling mill entrance.

<table>
<thead>
<tr>
<th>Commissioning</th>
<th>March 2011</th>
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<tbody>
<tr>
<td>Production capacity</td>
<td>2.5 million t/year (option: 3.5 million t/year)</td>
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<tr>
<td>Slab thickness</td>
<td>55 … 80 mm</td>
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<tr>
<td>Strip width</td>
<td>850 … 1,680 mm</td>
</tr>
<tr>
<td>Strip thickness</td>
<td>1.0 … 25.0 mm</td>
</tr>
<tr>
<td>Product range</td>
<td>Carbon steels (low, medium, high-carbon), Si steel, pipe grades, DP steels</td>
</tr>
<tr>
<td>Metallurgical length</td>
<td>8,065 mm (4 segments)</td>
</tr>
<tr>
<td>Liquid core reduction</td>
<td>LCR3</td>
</tr>
</tbody>
</table>

Table 1. Technical data of the CSP® plant at Essar Steel India.
Hot rolling mill. The seven-stand hot rolling mill, figure 4, processes the slabs into either thin strip down to 1.0 mm and heavy-gauge strip up to 25.4 mm. Flying gauge change allows producing strips even below 1.0 mm.

Downstream of the tunnel furnace, a height-adjustable high-pressure descaling system ensures a clean slab surface before start of rolling. In stands F1 and F2 the roll separating force is 45 MN, in stands F3 and F4 42 MN and in stands F5 to F7 32 MN. All stands are equipped with hydraulic adjustment systems, work roll bending and CVC® plus technology. Hydraulic loopers (F1 – F4) and differential tension loopers (F5 – F6) between the stands ensure stable strip travel also for thin final gauges. Besides the main and auxiliary drives, the electrical and automation X-Pact® system was supplied by SMS Siemag.

The strip cooling system uses selective cooling patterns. Edge masking is implemented to prevent excessive cooling of the strip edges, improving cold strip flatness. The optimum cooling strategy for each product is preset by the X-Pact® cooling model. It provides cooling curves for the laminar cooling system to be set as a function of the material properties to be attained.

Two fully hydraulic downcoilers have been optimized for straight-sided, closely wound coils for any steel grades and strip dimensions. The patented automatic step control system prevents marks on the inner wraps and protects the coiler’s mechanical equipment.

Safe and gentle transport to the coil yard is performed by a pallet system for horizontal coil transport, figure 5. As the individual pallets are separately controlled, coil transport operations are decoupled from the hot rolling process in the mill.

Automation system. To assure high quality, the strip surface condition is monitored by an inspection line. Downstream of the rolling mill, the geometrical characteristics such as thickness, width, thickness profile, flatness and strip temperature are measured and transmitted to the X-Pact® automation system. Like in the steel plant of Essar Steel India, also in the CSP® plant all information from the production process is centralized in the control pulpits.
The automation system of the CSP® plant was tested before delivery, using the tried-and-tested plug & work method. In SMS Siemag’s test fields, the automation system was tested under quasi-realistic conditions and optimized well before installation at the customer’s works. A simulation tool reproduces the entire mechanical equipment, the drive technology and the processes. In addition, the SMS Siemag employees trained the operating personnel of Essar Steel India on the authentic control desks. The personnel of Essar Steel India learned how to operate the plant in real operating situations (so-called virtual productive operation). The plug & work method considerably reduces commissioning time, accelerating the run-up phase and thus the return-on-investment (ROI).

OPERATIONAL RESULTS

The commissioning milestones were as follows:
- rolling of the first strip: 31 March 2011
- start of hot commissioning: 8 April 2011
- start of operation with two casting strands: 12 July 2011
- first strip with a thickness of 1 mm: 20 June 2011
- first strip with a thickness of 20 mm: 30 August 2011
- FAC: 31 October 2011 (first stage with two casting strands accepted).

Just three months after the start of hot commissioning, rolling with two casting strands was carried out. After seven months, the first section of the two-strand caster was accepted by the customer Essar Steel India. For documentation of the commissioning results, the following parameters have been considered:
- average casting time per ladle and availability of the caster,
- production start-up curve,
- cobbles rate,
- product mix,
- performance values attained for thickness, flatness, final rolling and coiling temperatures,
- rolling of thin and ultra-thin hot strip.

Figure 5. Coil transfer by individually controlled pallets.
During the first 16 months after start of commissioning, the following values were attained for the caster:

- on average, seven heats per casting sequence,
- max. 18 heats,
- 80 % availability of the caster ("steel in mould"),
- 98.6 % yield (ratio between thin slab weight and weight charged to the caster),
- average casting time per ladle: 70 min,
- average casting speed: 5 m/min,
- average throughput: 2.94 t/min,
- average casting thickness: 60 mm.

After start of operation with two casting strands in July 2011, monthly hot strip production exceeded the 150,000 t level for the first time in January 2012. However, as production had to be adapted to the market demand, the production capacity was only partially utilized.

After only 250 days following the start of commissioning, the designed daily productivity was for the first time exceeded, subsequently amounting to 130 %. (100 % daily capacity corresponds to the nominal capacity of the plant of 2.5 million t/year with two casting strands.) The Essar CSP® plant achieved a cobble rate of 0.05 % of the total quantity of all coils produced.

Figure 6 shows the development of the minimum (left) and maximum (middle) final thickness of coils produced from April 2011 to July 2012. The figure also shows the quantities of coils in the respective thickness classes. The lowest final thickness of 1 mm was rolled 57 days after the start of hot commissioning. The thickness of 20 mm was rolled 120 days after the start of hot commissioning. Approx. 20 % of the production was rolled down to final rolling thicknesses of less than 2 mm. 0.32 % of the production ranges between 15 mm and...
20 mm final thickness. During the above mentioned period, more than 90,000 coils were produced, including low-carbon, medium-carbon and high-carbon steels as well as peritectic grades.

**Quality data.** Final rolling thickness within the given tolerance is of utmost importance, and production results for produced coils are shown in figure 7. Approx. 95% of all measured values are within a thickness deviation of ± 10 µm. However, there is no differentiation as to the final thickness classes.

The results for flatness are summarized in figure 8, independently of the final rolling thickness and the final rolling width. In approximately 98% of the cases, deviation from flatness is within ± 15 i-units.

Since the final rolling and coiling temperatures are decisive parameters for the internal strip quality, these temperatures are within a very narrow range. As shown in figure 9, more than 96% of all measured values are within a tolerance range of ± 15 K.
**Thin and ultra-thin gauges.** The results of several successive thin-strip rolling campaigns are presented in *figure 10*. The aim was to roll thin strips of thicknesses of 1.5 mm down to 1 mm. The final rolling width was 1,000 mm. Coils ranging from 2 to 3 mm at the beginning of the sequence are typical of the structure of the rolling campaigns. Only five to seven strips at the beginning of the campaign are needed to achieve a final rolling thickness of 1.5 mm. In these particular campaigns, the final rolling thickness of 1 mm is maintained for around 30 strips before a roll change is performed and the next sequence starts. Using flying gauge change, Essar Steel India has also already produced ultra-thin hot strip of 0.8 mm thickness.

**SUMMARY**

Thanks to the perfect interaction between the proven process models and the control circuits tailored to the mechanical equipment and to the optimum preparation in the plug & work test, production results to the customer’s full satisfaction were achieved after an extremely short time. The successful commissioning of the steelworks and the CSP® plant at Essar Steel India once again demonstrated the advantage of having the mechanical equipment and the electrical and automation systems supplied from a single source.
"The information provided in this brochure contains a general description of the performance characteristics of the products concerned. The actual products may not always have these characteristics as described and, in particular, these may change as a result of further developments of the products. The provision of this information is not intended to have and will not have legal effect. An obligation to deliver products having particular characteristics shall only exist if expressly agreed in the terms of the contract."