Arvedi ESP – technology and plant design

The new Arvedi ESP® (Endless Strip Production) technology, a direct evolution from ISP (In-line Strip Production), is the first to apply a completely endless concept that connects casting and rolling without interruption, thus allowing a very thin transfer bar to enter the rolling mill to produce thin gauge quality steel in a very compact line (180m long) and with significantly lower energy consumption than a traditional cast slab hot strip mill route. Following commissioning in June 2009 the plant produced 400,000t that year. Since the start of 2010 production has averaged 300t/hr. The minimum gauge so far obtained is 1.2mm, while development down to 0.8mm gauge is expected by June 2010.

Authors: Gerald Hohenbichler, Federico Mazzolari, Bernd Linzer and Andreas Jungbauer
Siemens VAI and Arvedi

Arvedi ISP ESP® technology was developed to exploit the thermal energy of liquid steel to produce, in an effective and compact line, quality hot rolled thin gauge steel to replace cold rolled products.

The idea (patented worldwide as ISP®) was applied at the Acciaieria Arvedi steelworks in Cremona in 1992 as Europe’s first and the world’s second mini-mill for flat rolled steel based on thin slab casting. Implemented through the cast-rolling concept which, for the first time, connected casting and rolling without interruption, allowing a very thin transfer bar to enter the rolling mill, it consequently produced thin gauge quality steel in a very compact line (180m long) with significantly lower energy consumption than a traditional cast slab hot strip mill route.

The new Arvedi ESP® technology, a direct evolution from ISP, is the first to apply a completely endless concept. A series of innovations (covered worldwide by 420 Arvedi-owned patents) relating to the mould system (the shape and materials used in the mould and SEN), the bow-type caster and the induction heater are the basis for this technology, making it:

- The first industrial-scale plant using a new and unique mould system with liquid core reduction
- The first plant based on cast-rolling (the direct connection of the casting phase, achieved in a bow-type continuous caster, with the rolling phase in the special high reduction mill)
- The first application of a continuous induction heater (IH) for steel strip
- 15 years of excellent results confirm the validity of the idea, with average earnings (EBITDA) of 15%, 60% of the production mix in high added value special steels (high strength, low alloy HSLA, DP dual phase, etc), and more than 50% of production in quality thin gauges (1mm at full table width)

Fig 1 Layout of the Arvedi ESP line
FORMING PROCESSES

THE ARVEDI ESP LINE – CREMONA PLANT 2
The new cast-rolling line is made up of four main sections (see Figure 1).

The first section consists of a thin-slab caster followed by rolling in a linked 3-stand, 4-high reduction mill (HRM) at the exit of the continuous caster. An important factor in the internal quality of the cast slabs is that liquid steel core reduction is carried out with Smart® caster segments prior to the HRM.

The HRM rolls the slab with a special thermal thickness distribution (TTD), which is an inverse thermal profile, i.e., the core is hotter than the subsurface, which in turn is hotter than the surface. The low specific resistance to deformation in the core leads to improved material structure, excellent isotropic material properties, reduced energy consumption and a significantly improved crown.

After the HRM the transfer bar is 8–20mm thick and already has a flatness and thickness profile as well as quality parameters that fully satisfy the standards of hot-rolled coil and plate.

In the second section, the temperature of the intermediate strip is adjusted to the requirements of finishing rolling in an induction heater. The temperature of the strip is the key to good process performance in a fully continuous cast-rolling line. Induction heating allows highly flexible and precise control of the temperature and can also provide a high energy input within a very short space. More details are given later.

The third section comprises a high-pressure descaler to accurately remove scale and minimise temperature loss, and a 5-stand finishing mill equipped with the Siemens VAI SmartCrown technology package. It is designed to enable the rolling of strip to thicknesses between 12 and 0.8mm (and even thinner) at strip widths up to 1,570mm. The installation of an advanced cooling system at the exit of the finishing mill is an important pillar for the production of a wide range of steel grades including HSLA and multi-phase steels.

The fourth section consists of a high-speed dividing shear and downcoilers where the strip is coiled in weights up to 32t.

For ESP, the integration of technological automation systems and packages developed by Siemens VAI is a decisive factor for achieving excellent production and product quality parameters.

The core components of the plant have already been described in detail in various papers, and can be summarised, from a technological point of view, as follows: mould and caster, directly connected 3-stand HRM, intermediate area with pusher piler and sample cutting, induction heater and descaler unit, 5-stand finishing train and laminar cooling and high speed cutting units, all of which are essential to the success of ESP technology.

In order to create a highly profitable plant that produces high quality hot rolled coil with minimum energy consumption, and thus minimum conversion costs, the following components are of the utmost importance.

PLANT COMPONENTS
Thin slab caster The desired mass flow arises from a combination of the slab thickness (about 100mm) and casting speed and this determines the caster design. In our case only a low head bow-type caster with vertical mould and appropriate slab support system with a long...
metallurgical length fulfils the requirements for ESP operation. Moreover, casting speed must be taken into consideration as it directly determines the entry speed and temperature to the HRM. The process parameters dictated by the ultra-high casting speed, thin slab thickness and reduction obtained through liquid core reduction (LCR) determine the design features of the caster and demand highly reliable and flexible machine components. The main process figures and characteristics are as follows:

- High steel flow rate up to 5.9t/min
- Casting speeds above 6.5m/min, depending on slab thickness
- Flexible strand thickness – mould exit 90-110mm and strand guide exit 70-90mm

*Figure 2* shows the longitudinal section of the caster area including the main features and technical data. The low head caster has a metallurgical length of 17m and a bow radius of 5m. Important features of the thin slab caster ensuring high speed casting are:

- Funnel mould with high precision hydraulic oscillator and electromagnetic brake (EMBR)
- Slab guide segments with small roll diameters and roller pitches, including optimised secondary cooling
- Well-defined metallurgical length closely connected to the HRM

**Funnel mould** The mould, as the heart of caster, initiates the solidification process and is therefore crucial to thin slab casting with high mass flow. Collaboration between Arvedi and Siemens VAI on plant design and technology resulted in the design and construction of the mould system. Key features are:

- Proven and well-established funnel-shaped copper plates patented by Arvedi
- Fast mould cooling with heat removal of up to 4MW/m²
- Hydraulic narrow face adjustment for online taper and width corrections
- Advanced mould level control by fast eddy current system
- Instantaneous process feedback by Mould Expert
- Hydraulic oscillator for up to 450 cycles/min and possibility of online stroke, frequency and wave shape changes
- EMBR controls the liquid steel flow into the mould

An EMBR operates with a high mass flow and thus is very effective for influencing and controlling the liquid steel flow in the mould, achieving more stable conditions at the meniscus. It consists of four coils which, together with the core and yoke, generate the magnetic field. The coils with the iron core are retractable in order to have free access to the strand guide equipment below (see Figure 3).

**Strand guide segments** The first segment below the mould is the bender, which has some special features in order to fulfil several functions (see Figure 3):

- Tong-type segment with a mechanical joint on its top and a hydraulic clamping device on its bottom
- LCR with thickness reduction typically of up to 20mm, improving the material properties by less macro segregation and finer grains
- Bending of the strand through a continuous bending curve
- Application of powerful cooling equipment
- Remote and dynamic adjustment of the roll gap profile enables dynamic soft reduction (DSR) and gap closing/opening procedures for LCR

**Spray cooling** A maximum cooling rate of up to 3.5l/kg was designed and by applying a powerful cooling system and Siemens VAI’s dynamic cooling model, Dynacs®, extremely robust casting and high internal enthalpy at the end of the strand guide are achieved. The cooling system is split into two parts. High pressure water cooling at high flow rates in the bender and bow segments ensures high cooling efficiency to strengthen the initial strand shell. In the lower part of the machine, from the straightener to the last segment, air-mist cooling at normal pressure and flow rates enables a wide range of operation, predominantly to provide a strand of high and adjusted internal enthalpy to the first HRM stand. Depending on the casting width, the
centre and margin nozzles have different water deliveries so as to equalise the temperature over the width and keep the edge temperature high.

**ESP rolling mill area** The layout of the equipment is shown in Figure 4. Table 1 shows the design highlights.

**High reduction mill (see Figure 5)** This is located immediately downstream of the continuous casting machine and consists of three 4-high rolling stands, equipped with 3,000kW and 5,500kW motors. The main emphasis of the design is on reliability and trouble-free operation to allow up to 12 hours’ continuous operation.

Work roll material and roll cooling were the main challenges for the designers as the equipment is not only in operation for long periods of time but also has to withstand a rapid temperature rise at the start of operation. The wiper design was specifically engineered to ensure good sealing of the roll cooling water.

To control the profile of the strip a positive and negative work roll bending system was implemented to make use of the advantageous possibilities offered by the inverse temperature profile unique to this process, leading to particularly low deformation energy consumption.

**Tiltable heat conservation covers** These are mounted between the pendulum shear and the rotary shear in highly
reflective, robust, low heat capacity refractory material which very quickly rise to high surface temperatures. Thus, heat losses are minimised in this area, except for the start and end of the cast-rolling process. The pendulum shear is used to disconnect the dummy bar from the cast strand and to cut the transfer bar into plates discharged by means of the pusher/piler equipment, if chosen. The design allows a wide range of cutting thicknesses (10mm to 110mm).

**Induction heater (IH) and descaler** The IH units are located closely upstream of the highly efficient low heat loss descaler which, in turn, is followed by the finishing mill (see Figure 6). Both units allow the automation system to adjust the temperature of the transfer bar to the right values for finishing rolling operations.

The heating equipment comprises 10 induction coils of modular sealed-box design. Each module has an installed power of 3MW and can raise the temperature of the transfer bar substantially. The descaler consists of four high pressure descaler nozzle bars operating at up to 400 bar, delivered by a series of piston pumps.

**Finishing mill (FM)** The FM gives the product its final reduction and defines its geometric quality (thickness, profile and flatness).

To meet this requirement the machine is equipped with modern hydraulic actuators (long stroke cylinders, max 35MN), work-roll bending (T-block design, positive...
A high speed shear is used to determine coil size in endless operation. Positioned approximately 10m upstream of the downcoiler, it must be readily available and cut accurately. The equipment is made up of an entry and exit pinch roll unit and a rotary-style shear. The shear is of single-blade design (1 per drum) and works on the principle of an eccentric drive to activate the cut.

The three downcoilers downstream of the flying shear (2 operational, 1 standby) are designed for ultra-thin gauge production (4 wrapper rolls, air blow-down system, cradle roll indexing).

**PRODUCTION RESULTS**

Following commissioning in June 2009 the plant started production of strip for sale. For three months it worked with two shifts. In the 4th quarter of 2009 it moved to three shifts, taking production at year end to 400,000t. At the start of 2010 it moved to four shifts with an average production of 300t/hr. Figure 9 shows finished coils at the end of the compact plant.

Basic structural and high strength steels, soft steels for re-rolling and galvanising grades are currently produced in large quantities, and production tests have been carried out with HSLA steels with positive results. The minimum gauge so far is 1.2mm with excellent surface quality, structure and dimensional tolerances. Development down to 0.8mm is expected by June 2010, and a further
extension of the industrially and commercially produced steel grades portfolio is expected by the end of the year. **World record in energy saving** The ESP plant’s lower direct and indirect emissions of greenhouse and noxious gases (NOx and CO₂) are strictly linked to low energy consumption. They amount to 40-50% on normal gauges and 65-70% on thin gauges. The new concept will achieve the world’s lowest energy consumption for producing hot rolled coil from liquid steel. This is in part due to the reduced demand for deformation energy as the strip is rolled while still soft in the centre.

Arvedi ESP requires less energy when increasing line capacity and productivity, unlike other thin slab process technologies. The slab heat is used for the first reduction step in the HRM, with the advantages of the inverse temperature profile. Reheating of the transfer bar is done by the IH to the minimum required and just in time. During downtimes (turnover time between production sequences, maintenance shifts, etc) the IH is turned off.

Measurements have been taken during several production runs and have been compared to offline simulations for S235JR steel grade. After tuning of the models, reliable predictions can be made for different thicknesses and casting speeds.

**Figure 10** shows how thinner gauges result in an increase in energy consumption of 20% due to the higher deformation energy required if the final thickness is halved, whereas higher casting speeds lead to a reduction in energy consumption of approximately 20% for each m/min of casting speed increase.

Also promising is the use of thin gauge hot rolled strip instead of cold rolled strip, saving the energy needed for cold rolling, annealing and skin passing. The high quality thin gauges provided by the endless process will bring a steadily growing acceptance of thin gauge hot rolled coil.

Arvedi ESP offers the advantage, starting from a thin hot rolled product with excellent precision, dimensional and flatness characteristics, of 0.2–0.3mm gauges with a limited number of cold rolling steps, resulting in reduced investment and processing costs (see **Figure 11** and **Table 3**).

**PROSPECTS**

Energy savings of more than 60% against conventional production routes and up to 15% against the best available technologies (eg, ISP) have already been achieved in the six month start-up period.

Energy optimisation has just started, since the start-up curve is not yet finished, and with improved operational practice and casting speeds, further energy savings will be obtained. We expect that by optimising roll gap lubrication (especially beneficial in endless mode), even higher efficiency in the induction heater, minor improvements on the heat conservation panels and reduced water consumption by the descaler, a further energy saving of 10-15% will be achieved, leading to conversion energy savings of more than 25% with respect to the ecologically and economically best available technologies. **MIS**

**REFERENCES**