ISSN 1983-4764

ARVEDI ESP (ENDLESS STRIP PRODUCTION) FIRST THIN SLAB ENDLESS CASTING AND ROLLING RESULTS[1]

G. Arvedi[2]
F. Mazzolari[3]
J. Siegl[4]
A. Jungbauer[5]

Abstract

The Italian steel producer Acciaieria Arvedi SpA operates a mini-mill for flat rolled products with a single casting line (max. width 1300 mm) at its mini-mill in Cremona, Italy with an annual output of 1.3 mtpy of flat products using ISP (In-line Strip Production) technology, patented by Arvedi. Following this positive experience with its continuous thin slab casting and rolling process, improved in several stages over the years and resulting in a stable production unit of high quality hot rolled strip, it was decided to invest in a new line adopting ESP (Endless Strip Production) technology, also patented by Arvedi, a direct evolution of ISP. Due to its highly compact lay-out with a total length of 190 m, lower investment costs are incurred for an Arvedi ESP line compared with conventional thin slab casting and direct rolling plants. Production costs will also be noticeably lower than those of other thin slab plants and also of the ISP plant already operating in Cremona. Productivity of the ESP plant, based on a single casting line, will be about 2 mtpy for the first phase and a possible increase in mass flow from the caster may take capacity up to 3 mtpy. Total energy and water consumption of the Arvedi ESP process is very low compared with that of a conventional casting and rolling process: depending on the final product energy consumption will be 50-70% lower and water consumption 60-80% lower. Due to endless rolling operations, the production of strip with uniform and repeatable mechanical properties will be possible along the entire strip width and length and with the line's ability to produce ultra-thin hot rolled strip gauges of 0.8 mm (and lower), a subsequent cold rolling process will no longer be necessary for many strip applications. The Arvedi ESP plant is the first example of fully continuous production from liquid steel to hot rolled coil on the downcoiler in seven minutes and the Cremona plant will be the reference plant (master plant) for sales of future ESP lines. The aim of this presentation is to provide data relative to the new plant, commissioning and the first production results of the endless casting and rolling line. A contract was signed in 2006 with Siemens VAI as principal process and plant supplier of the new plant and construction is now completed in Cremona. Start-up is under way and will be concluded within the first half of 2009.

Keywords: Arvedi, ISP, ESP, endless

[1] *Technical contribution to the 47th Rolling Seminar – Processes, Rolled and Coated Products, October, 26th-29th, 2010, Belo Horizonte, MG, Brazil.*
[2] *Chairman, Finarvedi*
[3] *Senior Advisor, Finarvedi*
[4] *Vice President, Siemens VAI*
[5] *General Sales Manager*

ISSN 1983-4764

1 INTRODUCTION

Direct production of hot rolled strip by connecting the thin slab casting process with the hot rolling process was introduced around 1990. The most important technological achievements which made this possible were the developments in thin slab casting technology and direct processing in a hot rolling mill using higher casting speeds, newly developed refractory materials and better process control through automation.

2 METODOLOGY

2.1 The Value of ISP Technology

ISP technology is a unique technology for processing high quality, thin gauge, hot rolled strip. The solutions developed by Arvedi with its original ISP and cast-rolling technology were for the most part based on the concepts of clean steel production of liquid steel through technology based on symmetry, homogeneousness and constancy of the transformation process parameters from the liquid steel to the end product on the coiler.
ISP can be said to have 7 unique process benefits consisting in:

- the mould system and liquid core reduction, creating a sound slab centre with small grain size and uniform temperature distribution;
- thickness temperature distribution (TTD) with inverse temperature profile throughout the slab thickness with a core temperature >1200°C with a surface temperature >1100°C;
- cast-rolling (or in-line rolling) of the thin slabs at a slow speed in the High Reduction Mill (HRM) creating an intermediate bar with a very low crown of 2%;
- Induction Heater (IH) to increase temperature and create the desired temperature distribution, allowing the intermediate bar temperature to be set from coil to coil according to the optimal processing requirements;
- Cremona furnace, a heated buffer to stabilize temperature;
- a very thin bar entering the finishing mill;
- highly flexible operation of the rolling process in the finishing mill;
- automized planning and control for optimisation of all process parameters and products.

3 RESULTS AND DISCUSSIONS

3.1 The Advantages of ISP

ISP presents advantages from a process point of view:

- low rolling forces due to reduction in the high temperature region using liquid core reduction and high reduction mill (HRM) with consequent reduction in rolling energy consumption;
- stable and highly flexible process due to the setting of the casting and rolling process parameters.
- a wide choice of process parameters which can be adjusted to each strip;
- a wide range of medium – high quality products;

ISSN 1983-4764

- excellent homogeneity of microstructure and properties over the whole strip.

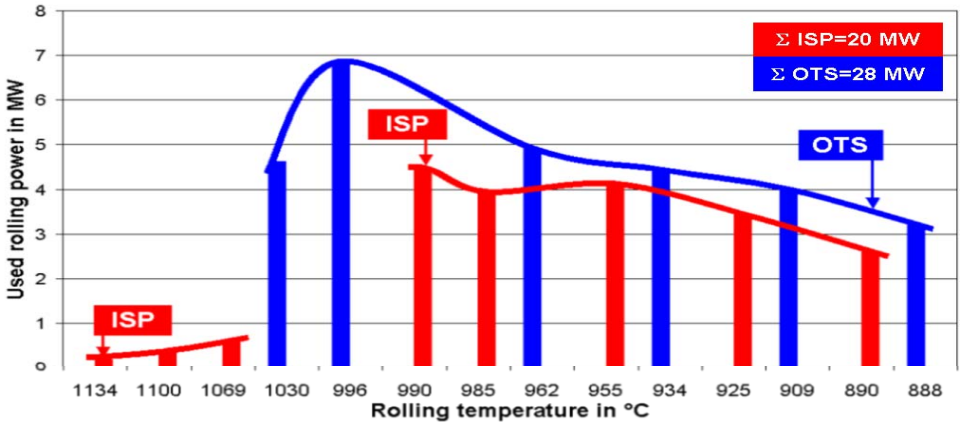


Figure 1. Rolling power as a function of temperature for ISP and OTS (Other Thin Slab technologies) for 1.5-mm strip

The main advantages from the investment point of view are:

- low investment costs due to the compact line and lean rolling stand lay-out,
- low processing costs because of excellent heat exploitation and stable processing.

ISP technology with its highly flexible process parameters follows the natural temperature development of the hot steel, the basis for the low investment costs and low production costs of this production line as well as the high quality of its products. ISP technology is covered by 20 patents worldwide for full protection of the process technology, its main technical components and special product lines.

THE TECHNOLOGY BEHIND ESP

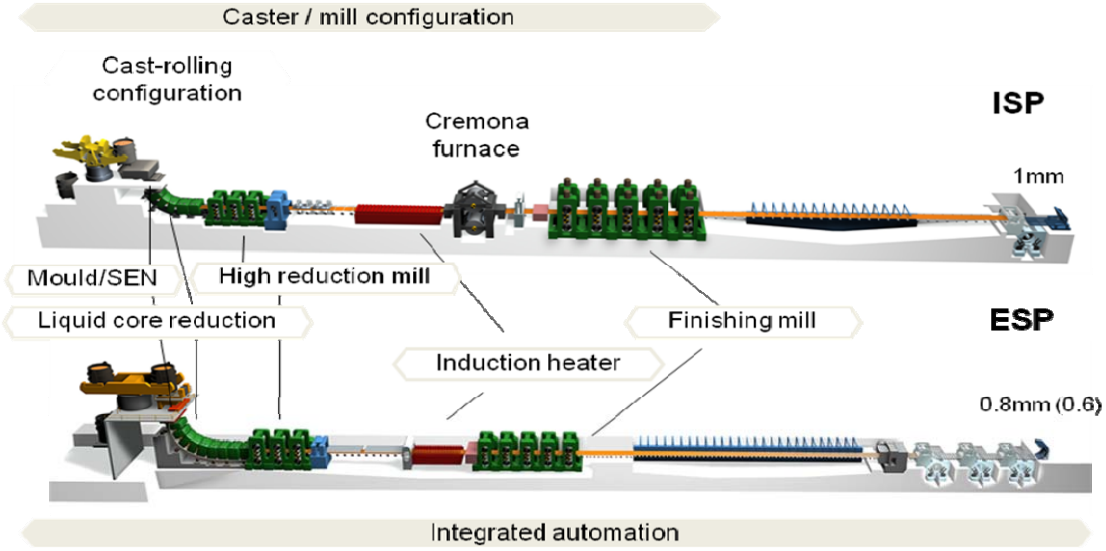


Figure 2. ISP and ESP lines.

The new Arvedi ESP endless line is the first plant of the next generation of thin slab casting and direct rolling lines and is characterised by:

- fully continuous strip production
- outstanding production capacity with a single casting line
- high volume production of ultra thin strip

ISSN 1983-4764

- high volume production of high quality strip
- the lowest conversion costs from liquid steel to hot rolled coil
- the most compact line lay-out

These steps, which enable endless hot strip production, are described in more detail in the following paragraphs.

3.2 Higher Casting Speeds

Endless production of hot rolled coil from liquid steel is only possible if a constant and high casting speed i.e. mass flow is achieved.
This is now possible with an optimized caster configuration flexible in thickness and casting speed range beyond the present state of the art. The design includes further development of the shape of the submerged entry nozzle together with the special Arvedi mould geometry. Mathematical simulations (computerised fluid dynamic calculations) and water model tests showed that the present casting speeds of 5 to 6 m/min can be exceeded by far, ensuring the necessary mass flow for endless production.
The theoretical results were confirmed by operation. A casting speed of 7m/min is regularly applied whenever possible in ISP plant operation

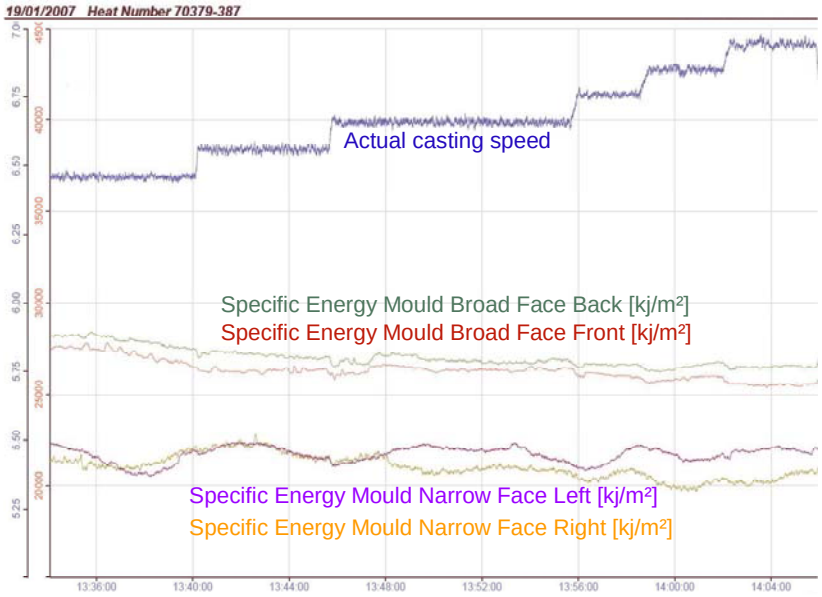


Figure 3. Casting speed results at 7 m/min

For speeds of over 6 m/min stabilization of the flow pattern and the meniscus using an electromagnetic brake (EMBR) is absolutely necessary and has been operating on the ISP plant since 2005, showing potential for further increasing casting speed and mass flow.

3.2.1 Process control during casting

The reliable control of initial slab solidification and shell formation in the upper area of the caster is the most important improvement of the last decade, requiring also the optimization of the casting powders for the different types of steel. By controlling

ISSN 1983-4764

friction and temperature distribution in the mould a high stability of operation at high casting speeds has now been achieved.

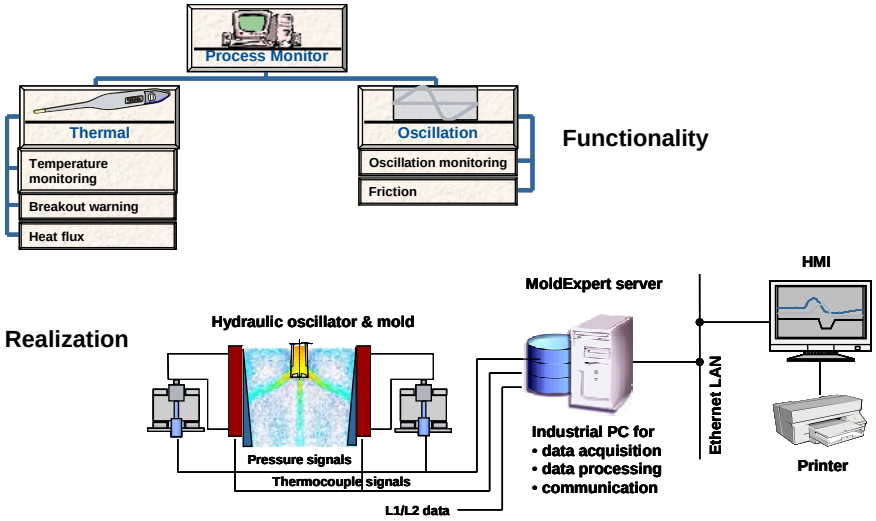


Figure 4. Process control scheme.

3.2.2 Slab guiding system

Operations are much more reliable thanks to the highly advanced design of the slab guiding system during liquid core reduction. An optimum combination of casting speed and slab thickness can be achieved, depending on the type of steel desired. For high mass flow a metallurgical length typical of a vertical thin slab caster is not sufficient. A bow-type caster has therefore been designed with liquid core bending and straightening, keeping the ferrostatic pressure very low. The tight roll spacing in all the segments and a very effective secondary cooling system result in much more favourable conditions, greatly reducing phenomena such as strand bulging with its negative influence on process stability and product quality.

3.2.3 Induction heating

Precise and flexible temperature control of the strip are achieved through the thermal loading capacity and power density control, resulting in accurate temperature adjustment for each steel grade for best strip quality and low energy consumption. The heating power of the induction heater is provided by a maximum of twelve 3-MW inductors.

3.2.4 Cast-rolling and finishing

The effective demonstration that endless strip production is feasible is the highly reliable operation of the existing ISP line where a high reduction mill is directly connected with the caster.

A highly reliable and stable caster is necessary in order to have stable rolling operations and to increase product quality and yield. SVAI in the last decade has introduced a new generation of profile and flatness actuators with the invention of the SmartCrown® Technology which is capable of controlling higher order flatness defects such as quarter buckles.

ISSN 1983-4764

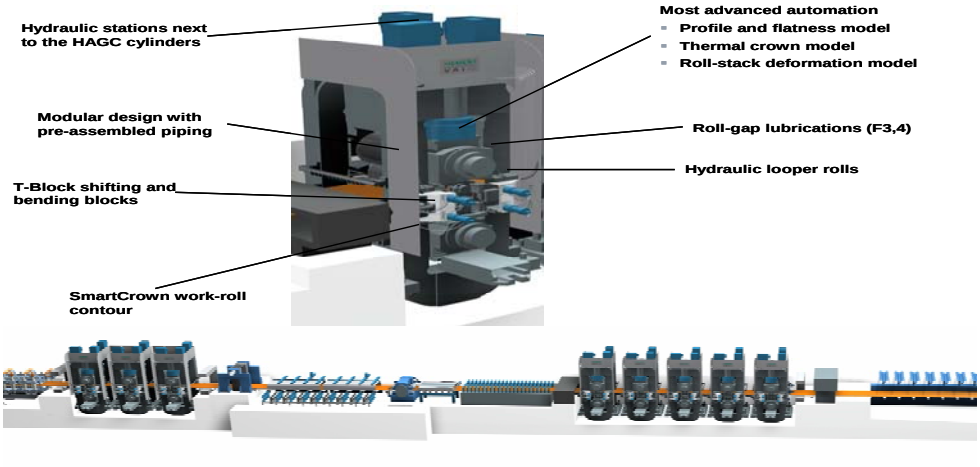


Figure 5. Application of SmartCrown® Technology

3.2.5 Automation

Improvements in process control such as speed control, sensor techniques, data management and process modelling are key points for success. Neuronal network process models are highly flexible and are standard in the Siemens VAI SIROLL product family for profile and flatness control. Another example is the “Micro Structure Target Cooling” package which controls the metallurgical parameters of the strip. In an ESP Line automation integrates all the individual process steps from casting to cooling.

The experience of Siemens VAI in this area is confirmed by its installation of key automation covering casting, hot rolling and cooling in over twenty plants worldwide in the last fifteen years.

THE ARVEDI ESP LINE – CREMONA PLANT 2

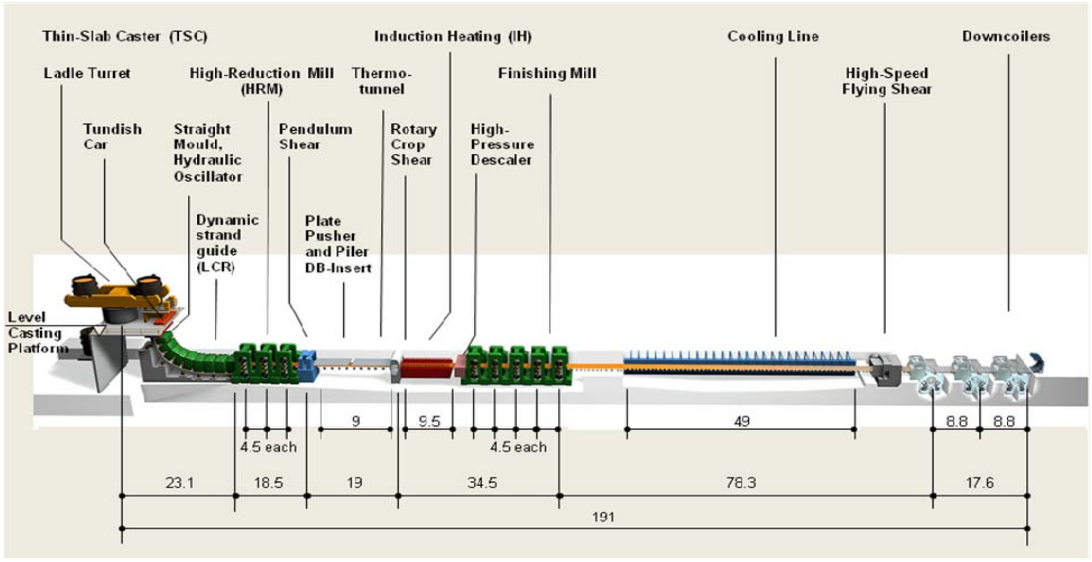


Figure 6. The Arvedi ESP line in Cremona.

The new Arvedi endless casting-rolling line will be composed of four main plant sections.

ISSN 1983-4764

The first section consists of a thin-slab caster followed by rolling in a linked 3-stand, 4-high reduction mill positioned at the exit of the continuous caster. As an important factor for the internal quality of the cast slabs, liquid steel core reduction is carried out with Smart®-type caster segments prior to the high reduction mill.
The High Reduction Mill rolls the slab with a special thermal thickness distribution – TTD (inverse thermal profile) not only in the subsurface area but also in the core. This low specific resistance to deformation in the core leads to:

- improved material structure;
- excellent isotropic material properties;
- reduced energy consumption;
- a greatly improved crown

After the HRM the 10-20-mm thick transfer bar already has a flatness profile and quality parameters that fully satisfy the standards of hot rolled coil.
Conventional thin slab casting and direct rolling lines using a vertical caster and tunnel furnace normally have a much thicker entry slab, typically 55 to 65 mm. To reach the same exit thickness a much greater rolling force is required per stand resulting in higher motor power, roll wear and more difficulties in achieving profile and flatness results, especially with the thinner gauges.
In the second section the temperature of the intermediate strip is adjusted in an induction heater for the requirements of finishing rolling.
The temperature of the strip is the key to process performance. Induction heating provides precise control of the temperature and can provide a high energy input within a short distance.
The casting and rolling production process presents a particularly favourable temperature diagram for the manufacture of steel grades, such as high silicon steels, with critical analyses. During the process the temperature never drops below 1000°C, so avoiding the formation of precipitates and raising the yield of alloying elements.
This phenomenon is closely linked not only to the temperature but also to the extremely short time factor. Arvedi ESP guarantees even better performances for alloying elements than conventional and other thin slab plants.
The third section is composed of a high-pressure descaler to accurately remove scale and also to 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 12.0 mm and 0.8 mm (and lower) at strip widths up to a maximum of 1,570 mm. The installation of advanced cooling systems at the exit of the finishing mill is the basis for the production of a wide range of steel grades including HSLA and multi-phase steels.
The fourth section consists of a high-speed flying shear which cuts the material just before the downcoilers where the strip is coiled in weights of up to a maximum of 32 tonnes.
The integration of the technological automation systems and packages developed by Siemens VAI is a decisive factor which allows ESP to meet stable production and product quality parameters.

3.3 Steel Range

3.3.1 The Arvedi ESP plant covers the entire production range

From low carbon soft steels to high carbon and alloyed steels the range includes top quality steels such as high silicon (for grain-oriented and non grain-oriented) and IF steels for exposed car body panels.

ISSN 1983-4764

With the Arvedi ESP plant it is possible to produce hot rolled products with quality characteristics allowing transformation into cold rolled products of surface quality (grade A) such as to be able to be used in exposed car parts, also using BOF liquid steel and with I.F.-type analytical characteristics.

- **ATG – Arvedi Thin Gauge**
  Large quantities of thin gauges (0.8 – 1 mm), which can replace cold rolled products for many applications, can be produced through the Arvedi ESP process since the problems connected with threading the material into the final rolling stand are avoided through endless rolling.
  - 1 mm for steels with yield limit up to 315 MPa
  - 1.2 mm for steels with yield limit up to 420 MPa
  - $\leq$ 2 mm for high strength steels up to 700/800 MPa
  - 1.2/1.5 mm for DP 600/1000

3.4 World Record in Energy Saving

Strictly linked to low energy consumption are the ESP plant's lower direct and indirect emissions of greenhouse and noxious gases (NOx and CO), amounting to 40/50% on normal gauges and 65/70% on thin gauges.
The new line concept will achieve the world's best energy balance for producing hot rolled coil from liquid steel reducing demand for deformation energy to a minimum 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 technology. At higher casting speeds, the Arvedi ESP energy balance at limit cases will drop to zero heat input in the induction heater.

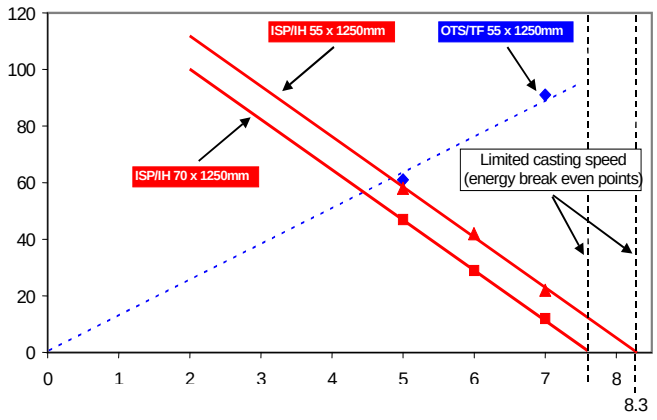
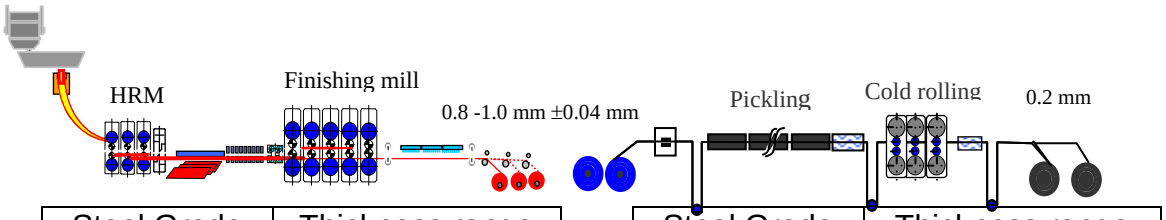


Figure 7. Casting speed in m/min.

Even more 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 obtaining gauges such as 0.3

and 0.2 mm with a limited number of cold rolling steps (lower investment and lower processing costs).



Steel Grade	Thickness range
DD12	190 m – 10.00 mm
S235 JR	0.85 – 12.00 mm
S315 MC	1.00 – 12.00 mm
S355 MC	1.20 – 12.00 mm
S420 MC	1.20 – 10.00 mm
S700 MC	1.80 – 8.00 mm
DP 600	1.20 – 5.00 mm
DP 1000	1.50 – 5.00 mm

Steel Grade	Thickness range
DD12	310 m – 2.00 mm
S235 JR	0.25 – 2.00 mm
S315 MC	0.30 – 2.00 mm
S355 MC	0.35 – 2.00 mm
S420 MC	0.35 – 2.00 mm
S700 MC	0.60 – 2.00 mm
DP 600	0.35 – 2.00 mm
DP 1000	0.45 – 2.00 mm

Figure 7. Hot and Cold Rolled products.

3.5 ESP Processing Costs

Direct processing costs are characterised by lower energy consumption (about 25-30% less compared with ISP and 40% lower than conventional hot strip mills), lower costs for consumables (mould, rolling cylinders etc.) and improved liquid steel yield (up to 98%).
The induction heater is an efficient device transferring about two thirds of the electrical power in heating the transfer bar.
On the basis of the experience of the Cremona ISP batch line in which there is a yield of 97% from liquid steel to top quality HR coil, a yield of 98% can be expected on the new Arvedi ESP plant.
ESP processing costs are drastically lower than those of ISP (20-25% less) and are almost 50% lower than those of conventional plants.
Estimated processing costs from the casting turret to the downcoiler for the Arvedi ESP plant with an annual production of 2.0 mtpy are €22-24/tonne. This cost considers European cost factors and does not include service and general costs.

OPEX COMPARISON – conversion cost from liquid steel to coil (€/tonne):

Integrated works	€44/tonne
Other thin slab technologies	€34.5/tonne
ISP	€31/tonne
ESP (2 mtpy)	€22-24/tonne

4 CONCLUSIONS

4.1 ESP – The best choise for profitable strip production

The advantages of the ESP process which have convinced Arvedi to invest in the construction of the first plant using this technology can be summed up as follows:

ISSN 1983-4764

the most compact process respecting the metallurgical transformation principle based on the cast-rolling concept;

- new machines, new lay-out, new products in a new process line with a unique lay-out for the manufacture of thin gauge coil;
- lower energy consumption and environmentally friendly due to fewer emissions;
- economical production of hot rolled thin strip, substituting many cold-rolled strip applications;
- significant cost savings due to short line length (190 m) and the direct linkage of the casting and rolling processes;
- production of high quality coils with uniform mechanical properties;
- fully integrated production facility incorporating advanced technological packages for overall plant reliability, superior products and a high line output;
- production mix including all grades extended to exposed car body quality;
- economical production of cold rolled strip down to 0.2 mm after cold rolling;
- limited capital expenditure per tonne;
- lower conversion costs;
- high added value product;
- highly flexible process with short time to market;
- highly profitable plant with fast pay-back.