Thinnest High-Quality Hot-Rolled Coils at Lowest Production Costs with Arvedi ESP Technology

ANDREAS JUNGBAUER*1

BERND LINZER*2

THOMAS PFATSCHBACHER*3

Arvedi ESP, developed by Acciaieria Arvedi and designed, manufactured, and sold by Primetals Technologies, has proven its capability to realize production of steel plates with excellent properties at a minimum production cost through continuous casting and rolling in endless mode operation. This paper describes the structure of the Arvedi ESP line and the results of operation.

1. Introduction

High-strength but lightweight car bodies, ultra-thin structures that possess the highest tensile strength, and lowest-possible production costs – innovative processes are required to meet the demands for automotive and other high-end steel applications. After years of successful operation in Italy, and with five additional lines ordered from China, today Arvedi ESP is accepted as a proven technology that provides innumerable rolling possibilities to meet the highest downstream requirements. The use of 0.8-mm-thin hot-rolled products as a cold-rolled substitute – either directly or by processing the hot-rolled coils in continuous pickling and galvanizing lines – makes the cold-rolling process unnecessary for many applications. Arvedi ESP was developed by Acciaieria Arvedi and is designed, manufactured and implemented by Primetals Technologies. Operational results of the new Arvedi ESP lines as well as possible configurations for Arvedi ESP and processing lines are described.

2. Overall plant configuration

The 180-m-long Arvedi ESP plants are far more compact than conventional casting and rolling mills. A short line length means that lower investments are required for land, civil works, buildings, piping, cabling and construction (**Figure 1**). Liquid steel for Arvedi ESP lines is either supplied from LD (BOF) meltshops or from Electric Arc Furnaces.

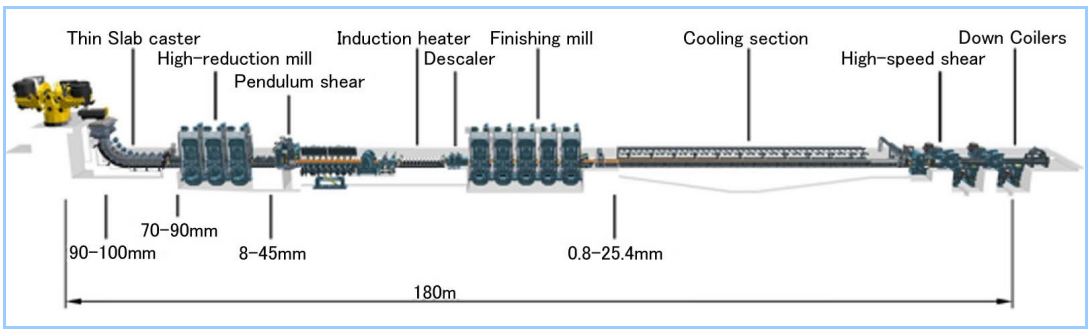

Figure 1 Layout and main components of Arvedi ESP plant

*1 General Sales Manager for Endless Strip Production, ESP Sales Department, Primetals Technologies Austria GmbH
*2 Head of ESP Technology, ESP Technology Department, Primetals Technologies Austria GmbH
*3 Head of Technology & Innovation, CE Casting & Rolling Technology, Primetals Technologies Austria GmbH

2.1 Continuous casters

The bow-type casters perform continuous strand bending and unbending, and they are equipped with a straight mold for the casting of steel at thicknesses between 90 mm and 110 mm. Online strand-width adjustments are performed using DynaWidth mold-width adjustment technology. This solution allows the target strand width to be accurately met without the need for an edger (**Figure 2**).

Figure 2 Funnel mold with special shaped Submerged Entry Nozzle

The casters are equipped with 11 strand segments each, and the metallurgical length of all casters is just over 20 m. Three high-reduction mill stands are installed immediately after the final caster segment in order to utilize the remnant heat energy of casting for the initial rolling step. In addition to major energy-cost savings, this enables perfect crown and wedge control to be achieved with work-roll bending, since the hot core of the cast strand is softer and therefore has a higher formability for shape control (**Figure 3**).

Figure 3 ESP caster directly coupled to high-reduction mill

2.2 Induction furnace

The intermediate strip exiting the high-reduction mill then enters the induction heater, which features a short length of only 10 m. This enables the strip to pass through the furnace in less than 15 seconds, which is decisive for minimum scale formation. Only one descaler – installed immediately before the five-stand finishing mill – is therefore required for the entire line. Unnecessary strip-temperature losses are thus avoided, allowing a more perfect control of the thermo-mechanical rolling parameters (**Figure 4**).

Figure 4 Induction heater

2.3 Finishing mill

Following reheating and descaling, the intermediate strip then enters the finishing mill equipped with five 4-high finishing stands. Because strip shaping has already taken place in the high-reduction mill, only the first two finishing stands are equipped with Smart Crown rolls that are designed with a bottle-shaped roll contour. This serves as the basis for final rolling of perfectly flat strip by the last three finishing stands, which are outfitted with conventional work-roll contours. Long-stroke shifting of the work rolls under load, which is regulated by a wear-compensation model, maximizes the service life of the rolls before surface grinding is required. What's more, thanks to the endless mode of operation in Arvedi ESP plants, strip impact on the rolls – typical for batch-operated plants during strip-head threading – is eliminated. This aspect also contributes to a significant extension of the work-roll lifetime. For example, in a typical production sequence comprising 3,000 tons of liquid steel, a total of 170 km of strip – with a considerable portion of 1-mm gauge – is rolled by the final stand (**Figure 5**).

Figure 5 Finishing mill

2.4 Strip cooling and coiling

Rolling is followed by laminar cooling after which tension-free cutting is carried out by a high-speed shear. The endlessly produced strip with coiled weights of up to 32 tons is distinguished by highly uniform geometrical and mechanical properties throughout its entire length. Because strip-head and -tail cropping is unnecessary with endless production, an average yield of more than 98% is achieved from liquid steel to the coiled product in Arvedi ESP lines. The fully integrated automation system enhanced with an advanced tracking model ensures exact cutting procedures and coil scheduling in accordance with production orders. The entire process, including all plant technology and automation systems, are protected by Arvedi and Primetals Technologies patents (**Figure 6**).

Figure 6 Laminar cooling, high-speed shear and down coilers

3. Varied product mix

The product mix of Arvedi ESP plants comprises low- and ultra-low- carbon steels, medium-carbon steels as well as high-strength low-alloyed (HSLA) and dual-phase steel grades. Thanks to the constant process parameters of endless operation, particularly with respect to the strip-temperature profile, production of advanced steel grades is accomplished with a far higher degree of accuracy compared to conventional casting-rolling processes. For example, over-alloying

is avoided during production of HSLA and pipe grades, which results in considerable cost savings for producers. The positive influence of endless operation on the metallurgical properties of the rolled strip is shown in a YouTube film (**Figure 7**).

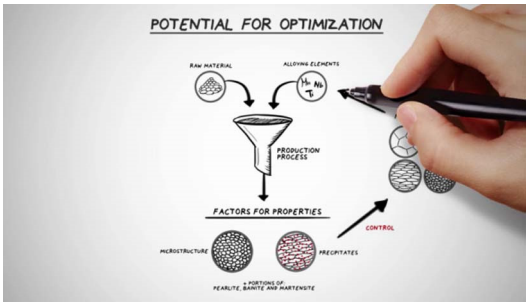

Figure 7 See why the Arvedi ESP endless production mode is superior for the production of new and advanced steel grades. https://www.primetals.com/PMF0028

4. Surface Quality – the key question

While geometry and uniformity of metallurgical properties were out of question right from the beginning of ESP demonstrations a further quality point turned into focus – the surface quality. To find the definitive answer, Arvedi ESP material from Cremona had been examined. Several coils went through the automotive production route for pickling, tandem cold rolling mill and finally coating Z100 on the galvanizing line.

The excellent geometrical constancy from head to tail paired with extremely low crown and wedge allowed the strip to run in the cold rolling mill smoothly without any fine tuning of the mill.

During cold rolling the flatness was observed carefully starting with 7 I-Units of input material after stand 1 featuring a final flatness of 1 I-Unit after cold rolling stand 5.

The strip was then further checked with the automatic surface inspection system confirming excellent results.

The test report was summarized as follows

- Hot strip geometry very good
- Thickness tolerances very good
- Width very good with only minor deviations
- Very good formability on cold Mill, strip was running perfectly
- Perfect flatness after cold rolling and galvanizing
- Practically free from surface defects

5. Direct usage of 0.8 mm hot rolled coil (pickled and galvanized)

Based on the excellent surface quality of ESP material the direct use of the thin gauge hot rolled strip instead of cold rolled strip is the only logic consequence. This generates savings of energy for cold rolling, annealing and skin passing (**Figure 8**).

Figure 8 0.8 mm Ultra-thin hot rolled coils

The most important requirements for direct use of strips for final applications besides the microstructure and the respectively defined mechanical properties are linked to surface and roughness. To convince of its capabilities to be directly used in further applications comprehensive

pickling tests of ESP hot rolled material were conducted. The micrograph showed that most of the scale is magnetite, with an average scale thickness of 9-10µm. The scale is rather homogeneously distributed along the strip width.

For testing a variation of pickling conditions was applied to learn about the behavior of ESP material. It was confirmed, that the material is absolutely comparable to conventional material in pickling conditions to be applied to get good results. Acid concentration, temperatures during pickling as well as the specific consumption of acid are not different to other materials (**Figure 9**).

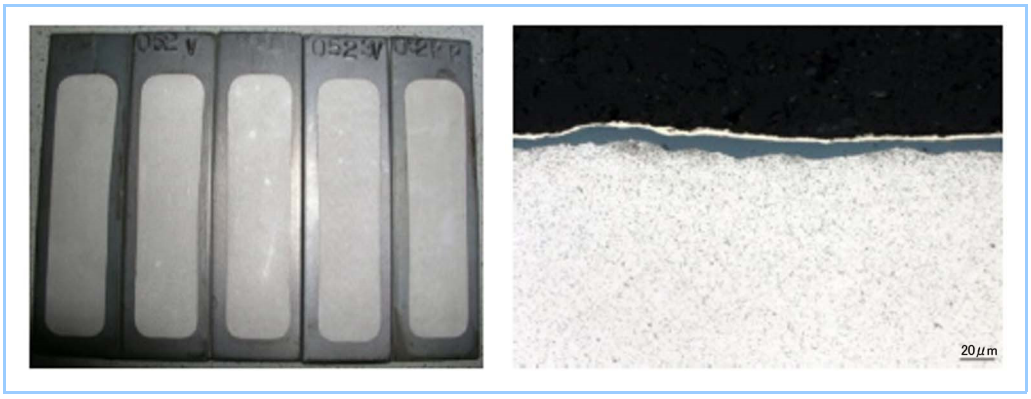

Figure 9 Several samples of pickling tests for variation of etching conditions and a typical micrograph of the scale layer of ESP material.

6. PAS 2050 – Green Certification

When discussions come to energy consumption or the emissions of greenhouse gases (GHG) it gets difficult to compare the given figures if not being a specialist in this field. Questions come up, like: What is included? What are the conditions? For which product are the numbers valid? Comparing and analyzing given figures, it is often the problem that you do not know whether you really compare apples with apples or just apples with pears. For this reason, specialists in this field have been consulted who applied the standard (PAS) 2050, issued by the British Standards Institution (BSI). It is a specification for quantifying the life cycle GHG emissions of goods and services. To comply with the requirements of BSI PAS 2050:2011, ISO 14040, and ISO 14044 Siemens VAI (the present Primetals Technologies Austria GmbH) and Acciaieria Arvedi had to collect a lot of detailed data and handed over a detailed documentation to TÜV SÜD Industrie Service GmbH, PE International AG. Additionally a critical review was made by PE International AG in Echterdingen, Germany which is a renowned specialist, in the field of life cycle analyses (LCA).

The GHG emissions are evaluated in a so called cradle-to-gate study and therefore the result is the product carbon footprint (PCF) of a defined product – the functional unit – including also the emissions from the used raw materials. As a well comparable product 1 t hot rolled low alloyed low carbon S235JR steel with a thickness of 2 mm and a width of 1500 mm was selected and all relevant energy and consumption data had been collected during the year 2011. The energy consumption of the production process depends on the alloys, the thickness and width of the finished strip, the final steel quality, the production technology (like Arvedi ESP), the production rate, the portion of recycling material and many other parameters. The production rate, when this product was produced, was 330 t/h which is a quite high value for a single caster but usual for Arvedi ESP.

The attestation and certification process was completed with an audit conducted at the Acciaieria Arvedi in Cremona, Italy by TÜV SÜD Industrie Service GmbH inspecting the whole process route including the interfaces between the different parts of the production process as well as mass and energy fluxes including losses that had to be accounted for in the calculation. Further subjects of the audit were checks of measurement devices and the data acquisition system. The attestation which is an integrated part of the certificate shows that the energy consumption of the Arvedi ESP is 131.6 kWh per functional unit. The certificate itself shows that the PCF is calculated correctly and the PCF per functional unit itself (**Figure 10**).

Figure 10 Attestation about energy consumption of the Arvedi ESP process and Certificate PAS 2050:2011 (2012)

7. Conclusion

The material coming from an ESP line can be excellently used to be sold directly in a wide range of products of the existing market. The material properties of the hot rolled material are comparable to a normalized grain structure after cold rolling. With such mechanical properties, the majority of the market can be served. If there are further requirements to the formability, as the Lankford value for drawing, the cold rolling step can be optimized as well by having the thin feed stock material of the ESP line.

The ESP product convinces by outstanding geometrical quality, surface quality, as well as the material properties for a wide range of applications, which is normally served by hot and cold rolled products.

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