CSP® – THE FLEXIBLE AND PROFITABLE TECHNOLOGY TO PRODUCE A WIDE RANGE OF STEEL PRODUCTS *

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Abstract
The situation of the steel industry is still challenging. Worldwide overcapacities have an impact on profitability. More than ever, the point at SMS group is to provide the steel industry with flexible and profitable technologies and systems over the whole process chain. One example for that is the thin slab casting and rolling technology and, in particular the CSP® technology (Compact Strip Production), being well established for hot coil production. From its introduction in 1989, CSP® technology has been continuously further developed. Today, on a CSP® plant, the full range of high-quality steel grades can be produced with tightest geometrical and metallurgical tolerances under optimal economic conditions. With the introduction of semi-endless rolling and, as a further step, the endless rolling process, the product range for thin and ultra-thin products has been further enlarged, allowing for the production of hot rolled coils with a thickness of 0.8 mm for low carbon steel grades. Also high-strength steel grades may be produced with gauges below the minimum product thickness that can be achieved in a conventional-type hot rolling mill. Another step in the further development of CSP® technology is digitalization. In December 2016, the CSP® plant of Big River Steel (BRS), located in Arkansas, USA was put into operation. It is the first learning steel mill in the world. The CSP® plant of BRS comes with innovative technologies, providing impressive operational results right from the beginning.

Keywords: CSP®, digitalization, PQA, Industry 4.0, advanced steel grades, economic production, learning steel plant.

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1. INTRODUCTION

Today, the world's steel industry is in a typical post-boom phase and is characterized by overcapacities. In this challenging situation, steel producers are working on the improvement of their competitive position by developing new and better steel products and by cutting their costs. Systematic digitalization of entire plants opens up new potentials as is shown by the Learning Steel Mill of Big River Steel, USA.

Figure 1: 4-stand CSP® finishing mill train at Nucor Crawfordsville in 1989

Another option is focusing on highly profitable market segments. The key products here are high-strength steels, the so-called AHSS steels with tensile strength of more than 1000 MPa.

At the same time, the expansion of electric mobility is being strongly promoted all over the world, resulting in an increasing demand for silicon steels required for efficient electric drives.

30 years went by since the market introduction of CSP®.since the first plant in 1989, see figure 1. Until today 28 CSP® plants were supplied worldwide by SMS group. Plant concept and technology have been continuously further developed in these decades. Figure 2 shows the development of steel grades being produced on a thin slab casting and rolling plant in an economic way.

Thin slab casting and rolling technology offers optimal pre-conditions for the stable production of large amounts of thin-gauge products, which may, depending on the relevant quality requirements, substitute cold strips [1] and therefore significantly save costs [2].

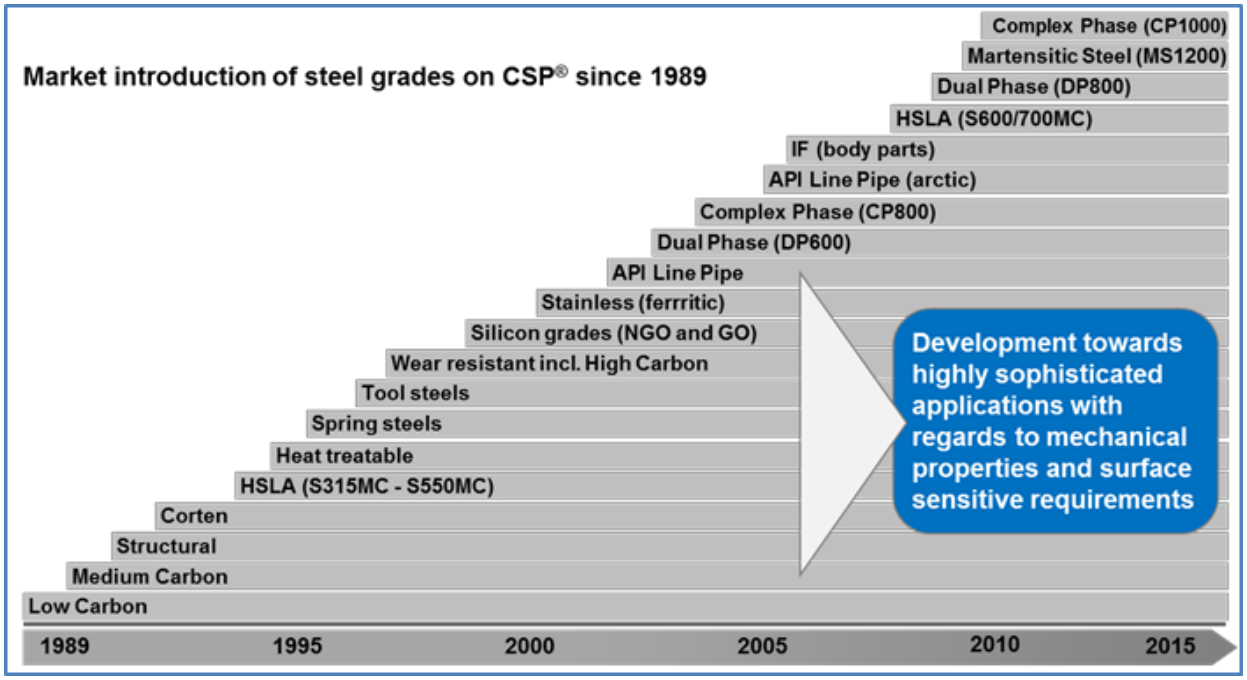

Figure 2: Development of steel grades on CSP®

2 BIG RIVER STEEL – THE FIRST LEARNING STEEL MILL IN THE WORLD

In spring 2017, Big River Steel opened a new steelworks in Osceola, Akansas, USA. Big River Steel banked on innovative technology from SMS group. In three years, a steelworks of the latest state-of-the-art was set up as a Greenfield project. The facilities comprise (figure 3):

- Gas cleaning plant
- Electric arc furnace
- Twin-ladle furnace
- RH degasser
- CSP® plant
- Coupled pickling line tandem cold mill (PL-TCM)
- Skin-pass mill
- Batch-annealing furnaces
- Universal annealing and hot-dip galvanizing line as well as
- auxiliary shops and plants.

All equipment was supplied by SMS group. The CSP® plant is the core part of the works complex. With the use of LCR, the casting thickness can be varied in the range of 55 mm to 85 mm. The strip thicknesses vary with the steel grade and range from 1.2 mm to 25.4 mm. At its maximum strip width of 1930 mm, the CSP® plant is the widest thin slab casting and rolling plant worldwide. The minimum strip width is 900 mm.

From the first planning to the detail engineering for every process stage, utmost importance was attached to the minimizing of energy consumption and to the use of innovative technologies for the cleaning of air and water. Big River Steel therefore sets new standards with regard to energy consumption and environmental protection and was the first steel mill in USA to be awarded the LEED (Leadership in Energy and Environmental Design) Certificate.
The entire new designed roller hearth furnace is equipped with environmentally compatible ultra-low NOx burners. At a measured average NOx emission of 85 mg/Nm³, the furnace of Big River Steel sets a standard with regard to environmental compatibility, see table 1.

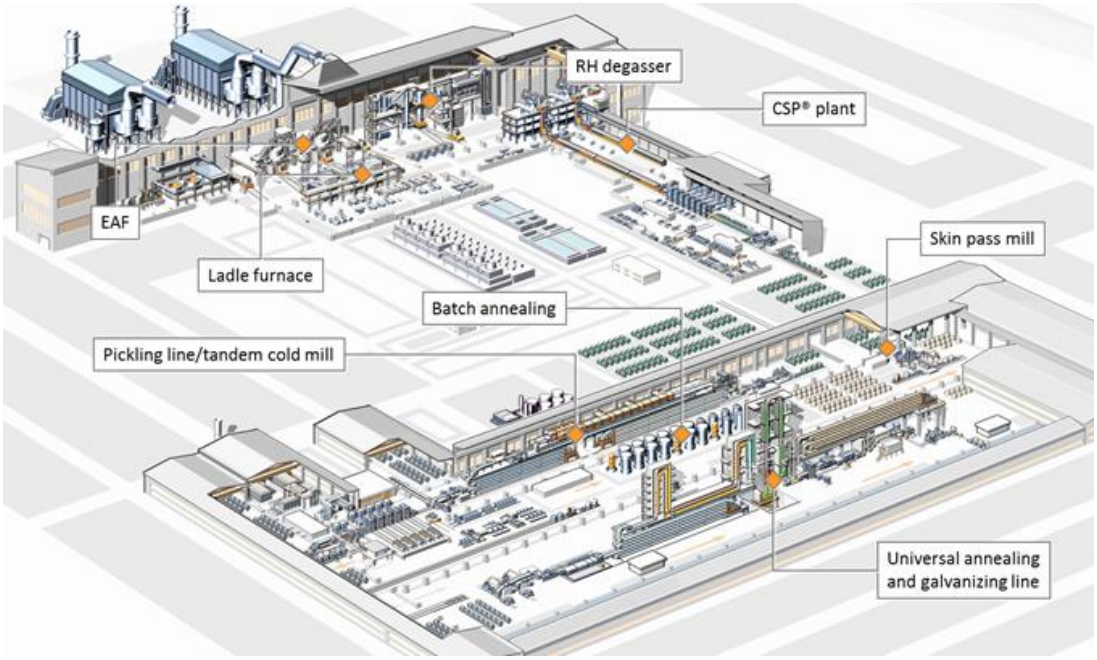

Figure 3: Layout of the BRS facilities

Table 1: Specific energy consumption in CSP® furnace for different slab dimensions

Slab dimensions and casting speeds	Mass flow in t/h	Specific energy consumption in kWh/(tm)
65 mm x 1600 mm 4.0 m/min.	189	0.542
65 mm x 1800 mm 4.5 m/min.	240	0.421
65 mm x 1800 mm 5.0 m/min.	267	0.352

2.1 LEARNING FACTORY APPROACH

The digitalization (Industry 4.0) of the works is the most important part of the Learning Factory Strategy of BRS (figure 4).

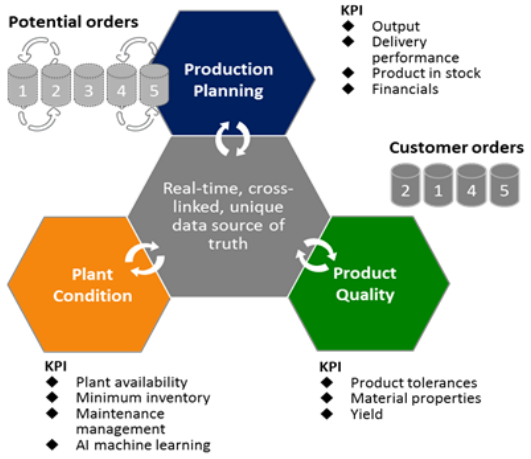

Figure 4: Learning Factory Strategy of BRS

All information and measured values needed for flexible production planning and integral evaluation of product quality and plant condition are made available to the overall system of physical and data-based models at different sampling rates and processed by the system. With the help of a Business Intelligent System, important KPIs (key performance indicators) and all information concerning product quality are evaluated and shown in a clearly arranged manner and the measures for the optimization of the whole works are derived.

In the overall structure of the Learning Factory, all systems are linked up with each other (figure 5). These systems include the newly developed SMS group systems MMS (Machine Monitoring System), PQA (Product Quality Analyzer), PCA (Production Condition Analyzer) and IMMS (Integrated Maintenance Management System), which were used for the first time all together at Big River Steel.

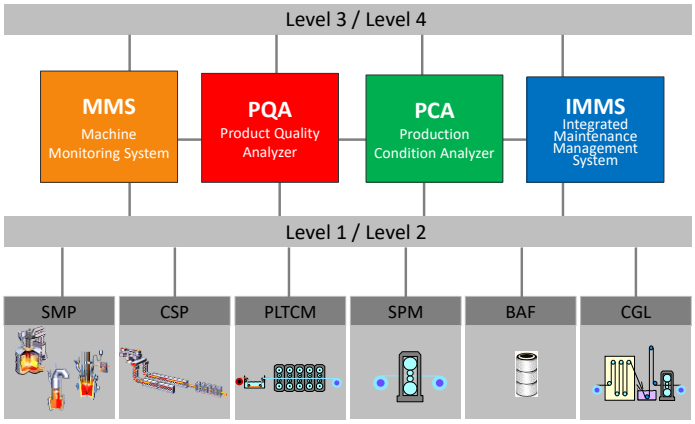

Figure 5: Components of learning factory concept of BRS

2.2 CSP® PLANT OF BRS

Its finished strip width of 1930 mm makes the CSP® plant of Big River Steel the widest of all such plants worldwide. In the first construction stage, the plant has an annual production of 1.5 million tons in single-strand operation with strip thicknesses ranging from 1.2 mm to 25.0 mm. The plant consists of a CSP® continuous caster of the VSB (Vertical Solid Bending) type, the newly developed CSP® tunnel furnace, the six-stand CSP® rolling mill, the laminar cooling system and a universal downcoiler (figure 3).

The CSP® mill is equipped with advanced technological control systems in order to further improve the stability of the rolling process. The Integrated Data Management System connects the entire CSP® plant with the preceding steel making plant and

the subsequent equipment for cold rolling and strip processing.

The CSP® plant produced its first strip on 10 December 2016 (figure 6). In January 2017, the first full month of production, a total of 58,000 metric tons. In early November 2017, Big River Steel surpassed the mark of one million tons produced on the CSP® plant with one strand. The cobble rate in July and August 2017, was lower than 0.06%.

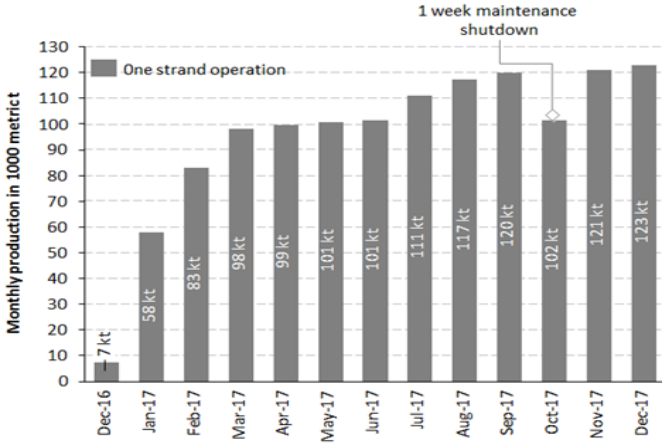

Figure 6: Start-up-curve of BRS CSP® plant

Many customers of BRS have their production facilities within a radius of 1000 km and expect very high flexibility with regard to product quality, product dimensions, lot sizes and delivery time. On account of the best plant dimensioning in every process step and the digitalization of the whole plant, all these expectations can be met at a mean lot size of only 7 coils. Almost 50 per cent of the strips produced have a width of more than 1500 mm. At present, BRS supplies 35 different steel grades to its customers.

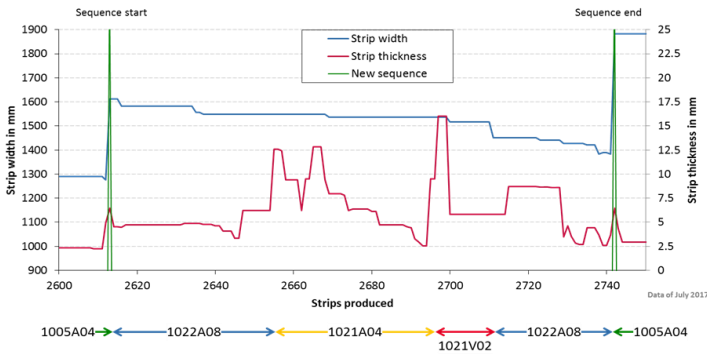

Figure 7: Rolling campaign with highest flexibility

The CSP® plant is of decisive importance for the flexibility of BRS. Within one sequence, considerable changes of the strip width can be effected. Thickness variations of up to 10 mm are realized from strip to strip (figure 7). Moreover, in the case depicted here, four different steel grades are cast within the sequence. This flexibility is a benefit yielded by the CSP® technology and a decisive factor of success for BRS.

3 UPGRADE AND EXPANSION OF CSP® PLANTS – THE ROAD TOWARDS INCREASED COMPETITIVENESS

3.1 EXAMPLE BIG RIVER STEEL

Steel producer Big River Steel has commissioned SMS group with the expansion of its steel plant in Osceola, Arkansas in March 2019. The expansion will increase the plant's annual output to about three million tons of steel. SMS group will again supply BRS with mechanical equipment, electrical and automation systems, and digitalization.

After completion of the next expansion, the steel plant will have two electric arc furnaces and two twin-ladle furnaces. Installation of an additional gas cleaning system will ensure compliance with the strict environmental legislation.

A second strand, a second tunnel furnace and a further downcoiler will be added to the CSP® plant. The hot coil produced in the CSP® plant is processed into high-grade cold strip in the downstream coupled pickling line/tandem cold mill. Also as part of this project, the continuous galvanizing line (CGL) will receive an additional coiler. For all the newly installed plants, SMS group is going to supply the mechanical equipment and the X-Pact® electrical and automation systems, including level 3.

Also in the second construction stage, the PQA® (Product Quality Analyzer) system developed by SMS group company MET/Con will be a central module of the process automation system. By capturing and evaluating all relevant production data on a continuous basis, PQA® monitors, documents and assures the product quality down to the finished cold strip along the complete production process. The system uses stored rules defined on the basis of expert knowledge to assess the coil quality in a semi-automatic procedure and, based on these assessments, takes “ship” or “block” decisions for the downstream processing of the strip or its dispatch. The system sends instructions for action to the operators while production continues in order to make them aware of any onset of irregularities within the production process and suggest countermeasures to be taken. This allows the operators to predictively intervene in the process before an incident becomes a problem, dramatically reducing the occurrence of failures along the production process which otherwise might have resulted in poor quality and downtimes. In the long run, the system provides higher yield while increasing the product quality.

3.2 EXAMPLE NUCOR STEEL BERKELEY, USA

Nucor Steel’s third CSP® plant at Berkeley site went into operation in 1996 as a single strand plant. In 2000, the hot commissioning of the second strand of the Nucor Berkeley CSP® plant took place.

Nucor Steel’s modernization goals were to increase the final strip width, to roll thinner strip gauges, to produce more higher-strength steel grades with better quality, and to reduce energy consumption (figure 8).

The widening of an existing CSP® plant can be executed only with exact knowledge of the detail design conditions in casting and rolling. For Nucor Berkeley, the maximum strip width was increased by 200 mm from 1680 mm to 1880 mm.

The technical highlight of the modernization at Nucor Berkeley is the installation of an induction heater behind the tunnel furnace, which is a solution that offers many advantages. The induction heater allows very flexible adapting of the slab temperature to the operational requirements.

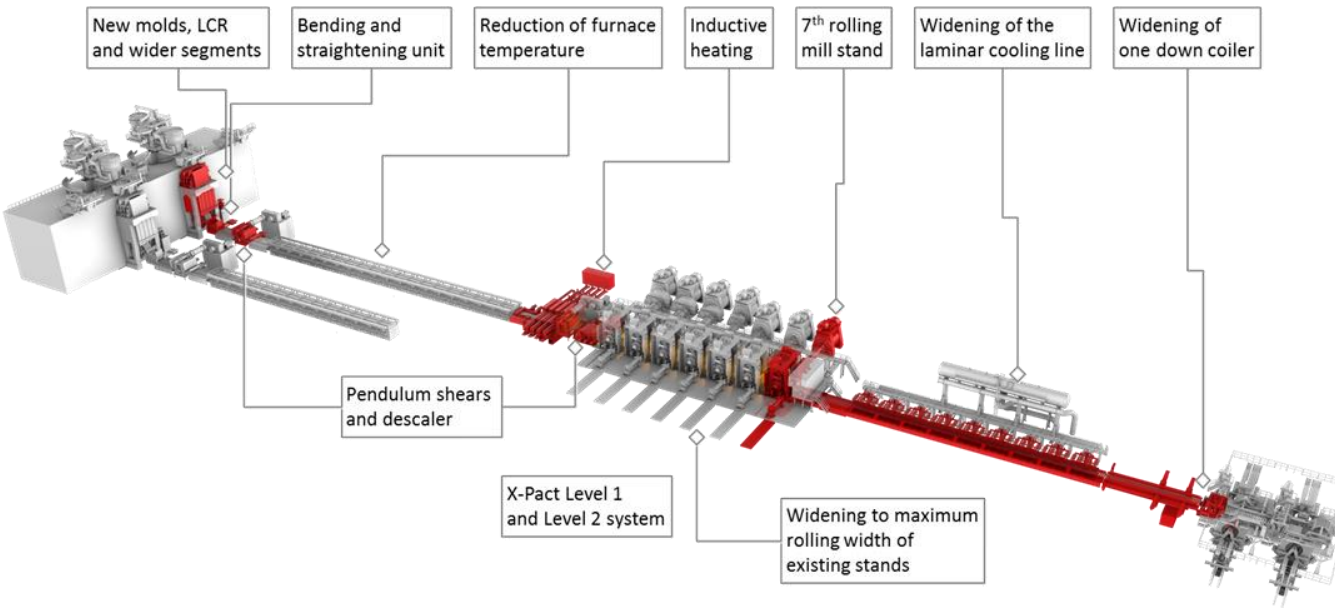

Figure 8: Modernization of CSP® plant Nucor Berkeley, SC, USA

On the basis of strip thickness and steel grade, the induction heater makes it possible to operate the tunnel furnace at a low temperature level and to thus reduce the energy consumption of the entire plant. The rolling of high-strength steels is facilitated by an elevated slab temperature.

Stepwise in 2014 and 2019 the maximium width of each caster was increased. In addition, the L1- and L2 automation systems for both casting machines and for the rolling mill were renewed.

4 ENDLESS ROLLING TECHNOLOGY – GUIDING CSP® INTO THE FUTURE

- Low FDT (Final Delivery Temperature) due to limited mass flow for LC steel
- Limited capabilities to control profile and shape at long rolling campaigns
- Economic operation of thicker gauges in endless mode
- Restrictions in cooling and descaling during rolling due to FDT requirements (surface)
- Process disturbances and/or restrictions during roll change

USP (Universal Strip Production) widely overcomes the a.m. limitations. The key features are the high-speed casting technology and the endless rolling technology together with the rolling mode interchangeability. The high-speed casting technology increases production capacity significantly with a single casting strand, which enables pure endless rolling to achieve sufficient mass flow and FDT.

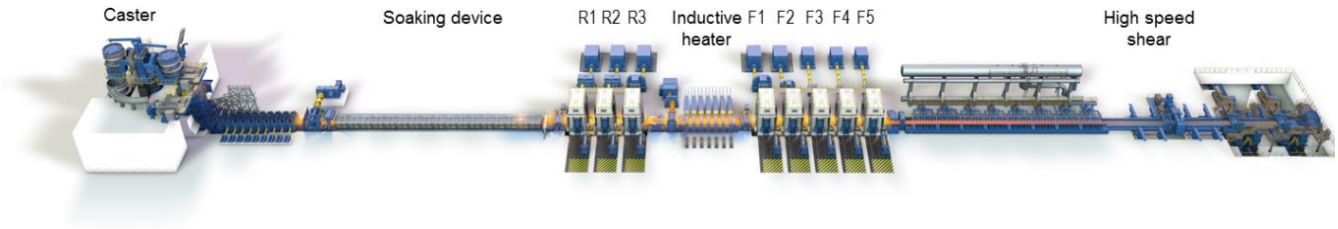

Figure 9: CSP® plant concept for endless and batch production

With all the advantages and developments of thin slab casting and rolling technology described above, the production of ultra-thin gauges (below 1.00 mm) for LC steel (Low Carbon) remained a challenge with a batch-type operation, in particular with high production shares. At the same time, with the wider spread of AHSS and UHSS steel grades e.g. for light-weight automotive design, there is an increasing requirement for production of high-strength thin-gauge hot strip. In particular, the threading-in and threading-out of the thin strips in the rolling stands provide a certain risk to interrupt smooth operation.

The main challenge for endless rolling is the high mass flow at the caster to assure the FDT (Final Delivery Temperature) in hot rolling. There are challenges remaining for applying endless rolling technology for a larger product mix and a wide range of applications.

The plant concept allows operation in both, batch and endless mode, see figure 9. It provides the opportunity to produce ultra-thin and heavy gauge strips at the same plant and assures the flexibility required to follow market requests.

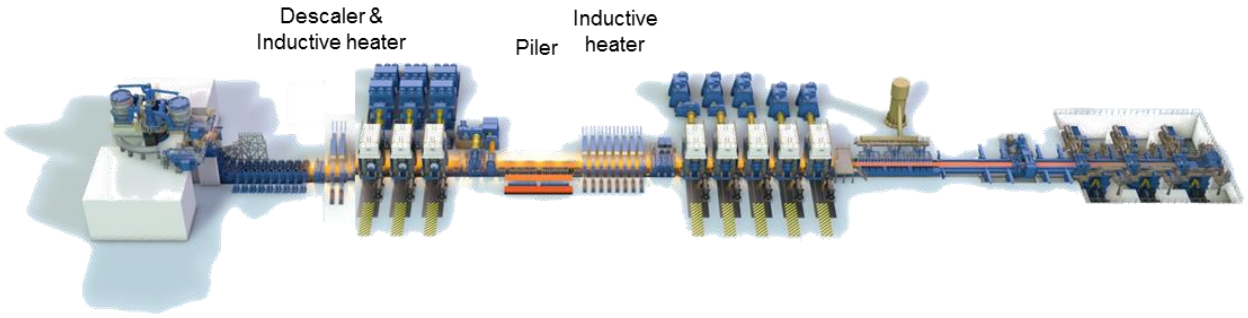

Figure 10: CSP® plant concept for endless production

A pure endless concept which allows for endless rolling only, without the possibility to de-couple the mass flow of the caster and the rolling mill, may be selected by large-scale steel producers that already operate one or more conventional-type hot rolling mills (figure 10). In such case, the product mix for the endless CSP® plant may be limited to such grades and dimensions which can be produced with benefit on that plant type, thus accepting a certain compromise for the flexibility of the plant.

5 CONCLUSION

CSP® is a successful concept for small and medium sized production facilities as explained at the example of BRS. Currently BRS is already expanding the new facilities.

CSP® technology, with production volumes of 0.8 million t/year to more than 4.0 million t/year remains the most flexible and economic thin slab casting and rolling solution.

Full implementation of digitalization opens further opportunities for increasing flexibility, quality and finally economic efficiency. Big River Steel (BRS) is the first example of a “Learning Factory”. This digitalization concept is also implemented in a Chinese plant at Shandong Iron & Steel Rizhao.

Well-defined modernization packages and implementation of innovative technologies can elevate existing CSP® facilities to state-of-the-art performance at low investment cost.

If high shares of thin and ultra-thin products are required different plant concepts for endless and batch rolling are beneficial.

REFERENCES

[1] W. Bald, G. Kneppe, D. Rosenthal, P. Sudau: Innovative Technologie zur Banderzeugung. Stahl & Eisen, 1999, 119 (7): 77-85.

[2] M. Jaenecke, H.-G. Klöckner, M. Cottin, C. Sasse: Economical Hot-Strip Galvanizing, Proc. GALVATECH 10th Conference on Zinc and Zinc Alloy Coated Steel Sheet, May 31 – June 4, Toronto, Canada (2015).