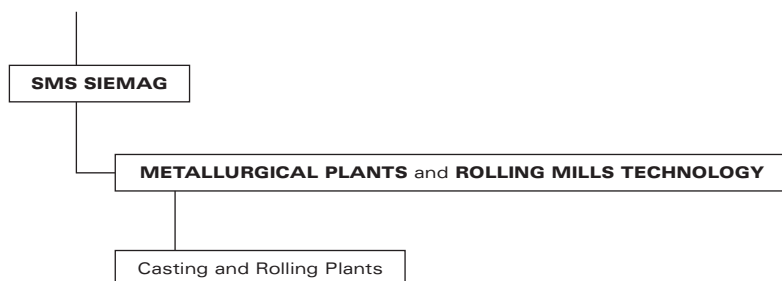
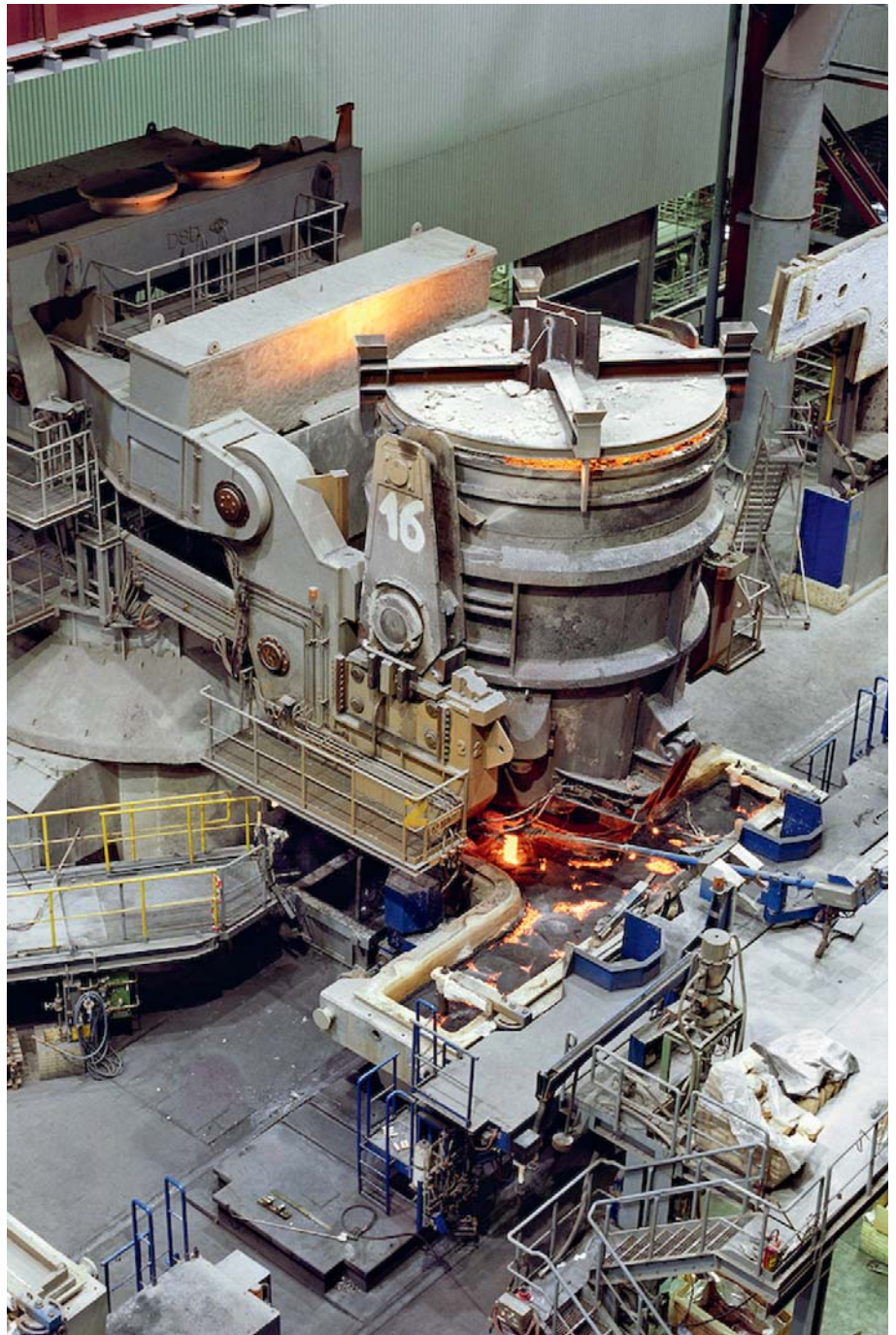


20 YEARS OF CSP®

Success story of an extraordinary technology





20 YEARS OF CSP®

Success story of an extraordinary technology

With the start-up of the first CSP® plant at Nucor in Crawfordsville, Indiana (USA), in 1989, SMS Siemag introduced the thin-slab technology in the market. 20 years after, around 52 million t of hot strip per year are produced in CSP® plants.

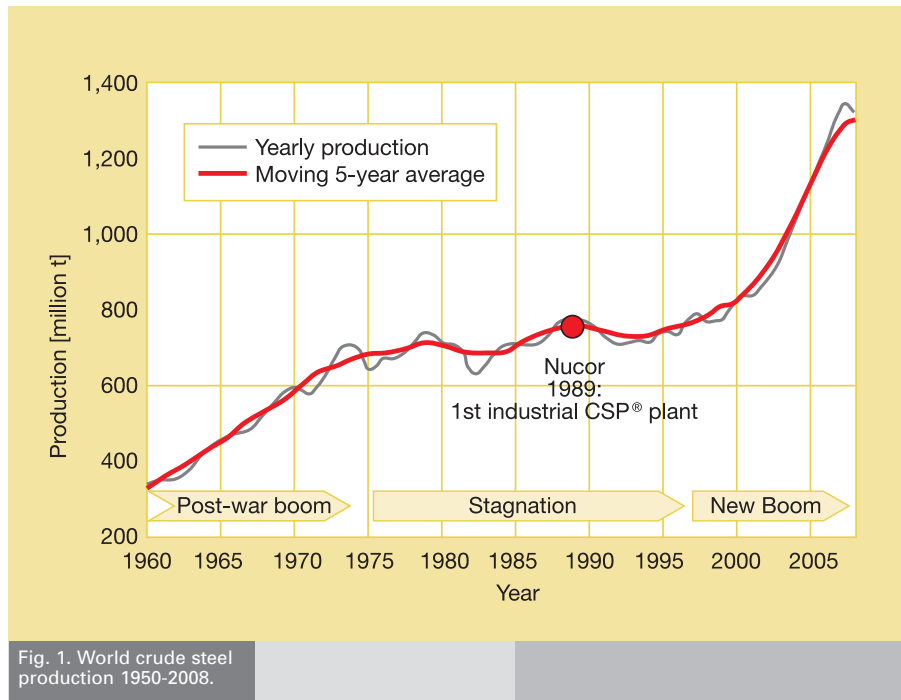
In times of high competitive pressure, rising energy prices and a growing environmental awareness, CSP® gives the right answers. In addition to the benefits of the technology, the present paper describes the different requirements made by CSP® users, discusses alternative concepts and provides an outlook to the future.

Pioneering innovations are rare in a highly developed industry like the steel industry. Indeed, the most recent innovation that has changed the steel industry in a lasting manner was the thin slab technology, which was introduced onto the market by SMS Siemag under the name of "Compact Strip Production" (CSP®) in 1989.

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all SMS Siemag AG.



Funnel-shaped mould and submerged entry nozzle: core of CSP® technology.



New PLANT CONCEPT for a CRISIS-RIDDEN INDUSTRY

The development of the CSP® technology coincided with the first serious crisis of the steel industry in post-war times, **figure 1**. As a result many companies were forced to cut overcapacity. The necessary investment in new, competitive machinery and plants was stopped [1]. In the same period, so-called minimills established themselves in the field of long products. Thanks to steelmaking on the basis of low-price scrap and by featuring an adapted rolling stage, they were capable of producing at much lower cost and more flexibly than integrated iron and steel mills. This scrap-based steel production allowed the minimill owners to operate independently of large-scale works infrastructures and also enabled them to establish their works close to their customers [2].

Against this background, in the 1980s, steel companies and plantmakers discussed alternative process configurations also in the field of flat-rolled products. At that time the benefits of “near-net-shape” casting had already been discussed many times and investigated theoretically. The aim was to apply only the mini-

imum amount of deformation necessary in the rolling mill to take account of the material and shaping requirements and thus make it possible to reduce the investments in the rolling stage.

However, its implementation had by the mid-1980s failed due to the technical challenges. The breakthrough in this question was achieved by SMS Schloemann-Siemag AG, the predecessor of SMS Siemag, in October 1985 when the first thin slabs with a gauge of 50 mm were successfully cast on a pilot plant in Kreuztal-Buschhütten, **figure 2**. The core of the new technology were the patented funnel-shaped mould and the optimized submerged entry nozzle. The caster was designed as a vertical bending machine, a well proven type of machinery which is characterised by its ease of handling [3].

To allow the further processing of the thin slab, SMS Siemag introduced a plant concept in which a roller-hearth tunnel furnace is used for connecting the caster with a hot rolling mill. In this concept, the thin slab is cut to the required coil weight immediately after exiting from the casting machine. After the temperature equalization has been made, the thin slab is



Fig. 2. Birthplace of the new technology: pilot plant in Kreuztal-Buschhütten (Germany).

accelerated in the roller-hearth tunnel furnace and fed to the rolling process. Due to the reliable production of thin slabs with a minimum thickness of 50 (40) mm, the scope of the rolling stage could be reduced to the finishing mill. In view of the short process time from liquid steel to hot strip and the compact layout, this plant concept was given the name "Compact Strip Production" (CSP®), **figure 3** [4].

COST and PROCESS BENEFITS

The economic benefits of CSP® in respect of investment and conversion cost are obvious. Through the deletion of the roughing mill and an adaptation of the finishing mill, the cut in investment cost is considerable. The production of hot strip "in one heat" reduces the energy input and hence the processing cost.

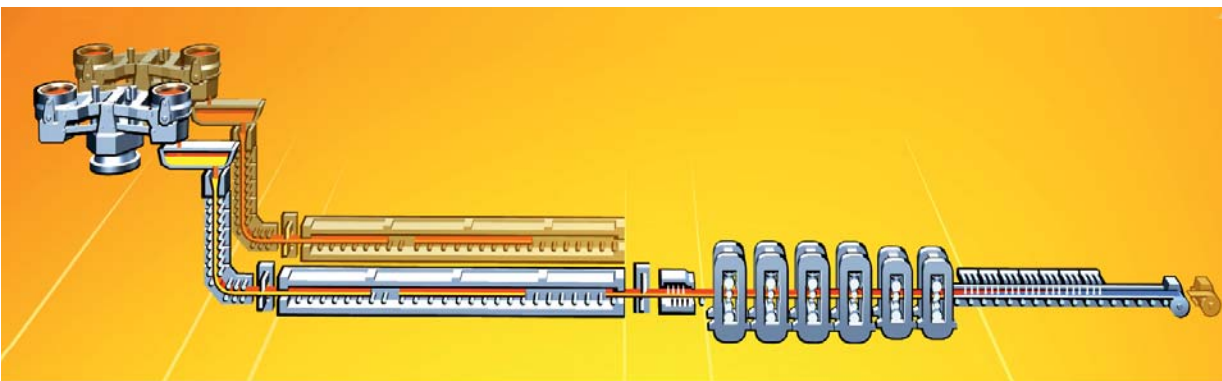
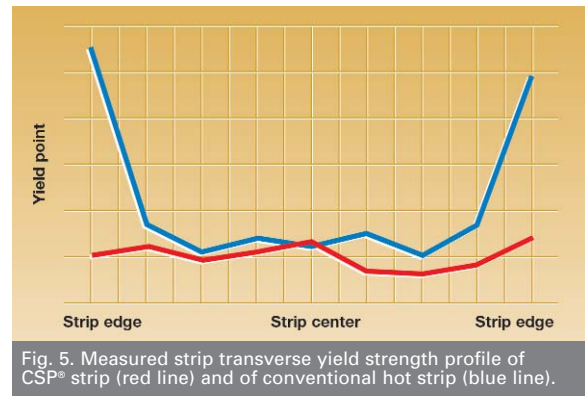


Fig. 3. CSP® plant concept.

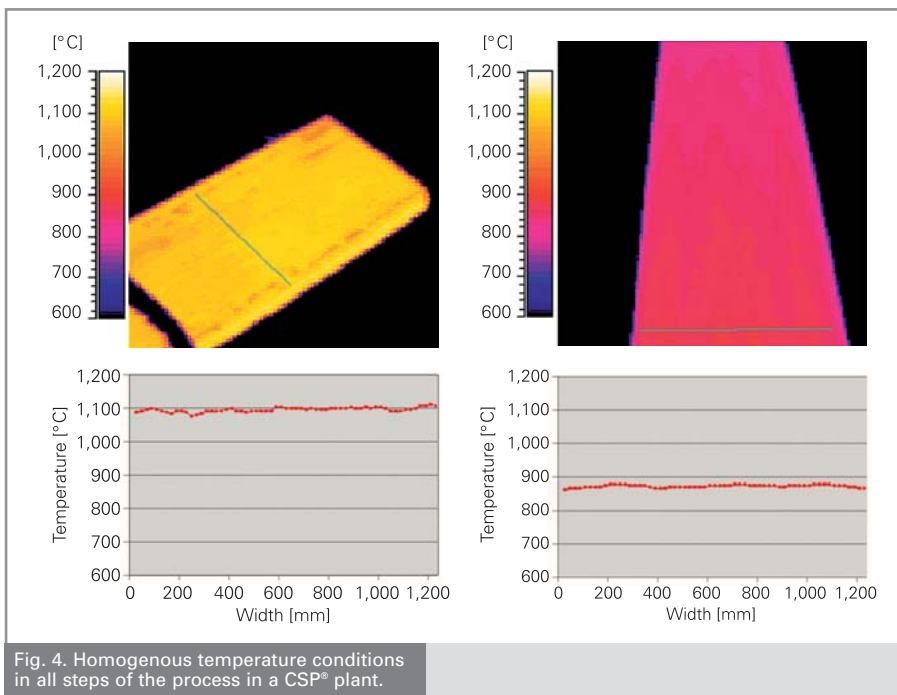
This plant concept allows the cost-effective operation already from an annual production of around 800,000 t. The maximum production capacity of 3.5 million t/a, for example, is attained by operating three casting strands.

The expansion options provide owners with a high degree of flexibility in adapting their production capacity and represent an essential factor of success of the CSP® technology. They allow CSP® owners to establish themselves in the production of hot strip with little investment and then grow along with the market. Thus, twelve of a total of 28 CSP® plants first started with one casting strand and underwent expansion later on.

In addition to the economic benefits, it is the special process conditions that contribute to the lasting success of CSP®. CSP® offers ideal conditions for a very homogeneous microstructure and constant mechanical and geometric properties of the hot strip. The reason for this is to be found on the one hand in the thin slab itself, since in comparison with a thick slab it solidifies a great deal more quickly. Its casting structure displays a smaller number of macrosegregations and very finely distributed precipitations.



On the other hand, the reason for the excellent product properties lies in the rolling process. On leaving the furnace, the thin slabs exhibit a virtually constant temperature over their width, thickness and length. There is also no longer the problem of “cold edges” which arises in conventional plants, nor the related coarse grain formation in this area, **figure 4**. As a result, more uniform mechanical properties are obtained over the whole width and length of the strip, **figure 5**. The constant conditions also provide an extremely stable, trouble-free rolling process, thus enabling the strip geometry to be within close tolerances.



Flexible CSP® CONCEPT

The machine concept inherent to a CSP® facility essentially comprises a vertical continuous caster, a roller-hearth furnace and a compact hot rolling mill with laminar cooling and a downcoiler unit. Within this basic concept there is a large number of design options to adapt CSP® to the customers' individual requirements. In the area of the caster, options range from machines with two segments and a metallurgical length of 5.7 m to five segments and 10.3 m metallurgical length. Casting thicknesses between 40 and 90 mm were realized.

The tunnel furnace serves for connecting the casters to the rolling mill and for equalizing the temperature of the thin slab. The length of the furnace is determined by the sufficient buffer capacity for a roll change and by the option of coupling several casting strands.

In the CSP® finishing mill, units with four to seven mill-stands were realized, the maximum drive torques ranging from roughly 2,000 up to around 4,000 kNm in the first finishing stand.

Other machine concepts are definitely also conceivable in each stage for the production of steel strip from a thin slab. For a casting thickness of 90 mm and more, SMS Siemag offers the supply of a bow-type continuous caster with CSP® funnel-shaped mould. In order to connect the casting and the rolling it is possible to use, besides to the equalizing furnace, thermal hoods, a coilbox and inductive heating systems, or a combination of these elements. The rolling mill can be extended by one or more roughing stands. Where the corresponding production capacity is demanded, a Steckel rolling mill is also conceivable as a finish-rolling stage.

All these variants are still being discussed today and to some extent have also been implemented. Thus, SMS Siemag has also built facilities with one or two roughing stands and a coilbox, **figure 6**. In 26 out of 28 CSP® facilities, however, the original concept has been implemented as it is the most economical solution.

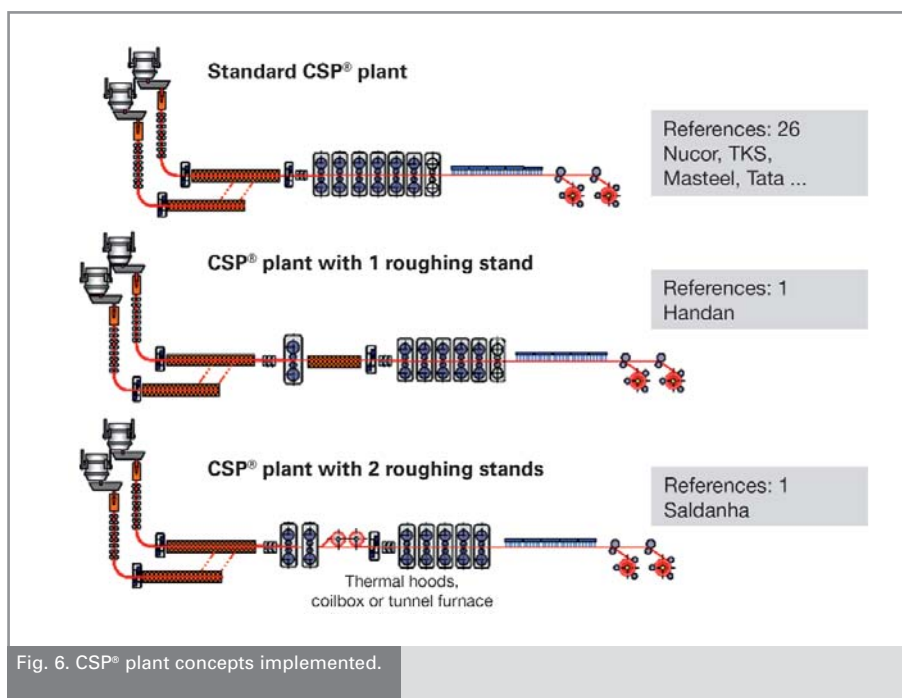


Fig. 6. CSP® plant concepts implemented.

CUSTOMER DEMANDS on CSP®

The success of the CSP® concept is all the more remarkable on considering that the customers’ objectives with regard to investment in CSP® have changed greatly over the past 20 years, **figure 7**. What began as a concept for the cost-effective production of simple tonnage steel is today being used purposefully by established steelmakers for the manufacture of high-quality steel grades. This development underscores the importance of CSP® as an innovation.

Cost-effective production

In the first CSP® facilities, priority was definitely given to the cost advantages of the new technology. CSP® offered the opportunity to enter the market under conditions of clear-cut investments and definite cost benefits in comparison with integrated steel plants.

In view of these arguments, numerous firms showed an interest. Even so, the first company to have the courage to really invest in CSP® was Nucor. At the end of the 1980s Nucor was already operating a number of minimills for long products and now wanted to obtain

a footing on the flat-steel market. In July 1989 the first CSP® facility commenced production in Crawfordsville (Indiana), **figure 8**. The plant was designed for strips with a width of 1,100 to 1,350 mm and a gauge of 2.5 to 12.7 mm. It possessed one casting strand, a roller-hearth tunnel furnace and a four-stand mill train with a coiler and was thus reduced to the absolutely necessary components.

Nucor’s calculation paid off. A mere year later, Nucor placed an order with SMS Siemag for the second CSP® facility, which went into operation in 1992 in Hickman (Arkansas). In 1994 both facilities were extended by a second casting strand, and in 1996 Nucor’s third CSP® plant started in Berkeley (South Carolina). The success of these dynamized the US market and this encouraged further companies to emulate these achievements, like Gallatin Steel and SDI (both 1995).

Even the CSP® plant of SeverCorr, **figure 9** (commissioned in 2007, today Severstal Columbus) followed this model. Here, the CSP® plant is the core of a works complex comprising all process steps from steelmaking to hot-dip galvanizing which was entirely delivered by SMS Siemag.

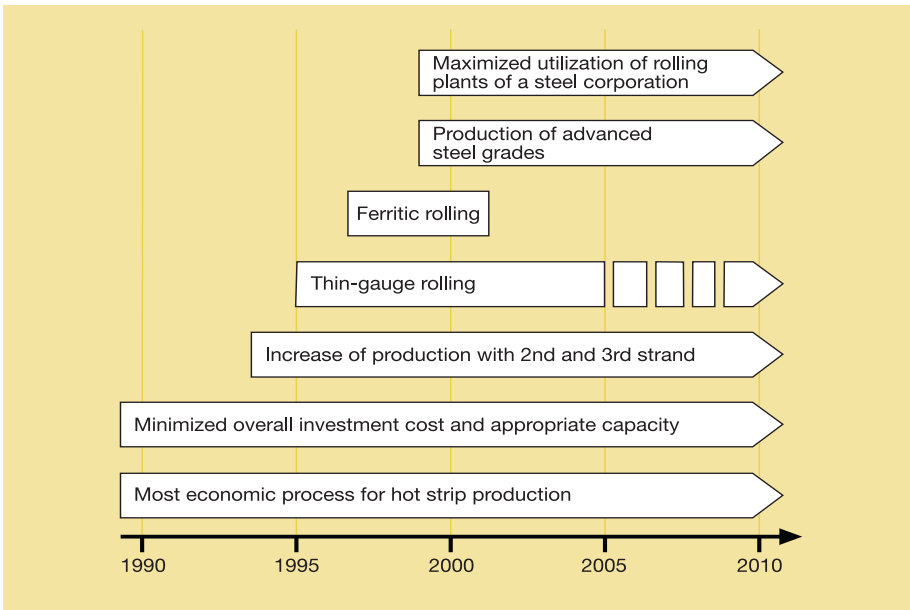


Fig. 7. Changing market and customer demands on CSP® since 1989.

Companies all over the world have used CSP® to enter the flat-steel market. Most of them were based on electric steelmaking using scrap or direct-reduced iron as raw materials. An exception from the above are the Chinese facilities of Handan Iron & Steel (1999), Baotou Iron & Steel (2001), Masteel (2003), Lysteel (2004) and Jisco (2005). These plants have been integrated

into conventional steel plants with blast furnaces and converter meltshops which the companies already had at their disposal. Following their successful entry into the market, Handan Iron & Steel and Masteel expanded their hot strip capacity by means of conventional hot strip mills from SMS Siemag.



Fig. 8. 4-stand CSP® mill at Nucor Crawfordsville.



Fig. 9. CSP® mill at Severstal Columbus, USA.

The example of Bhushan Power & Steel shows that the business model on which the first CSP® plants were based, i.e., entering the flat-steel market with a plant reduced to an absolute minimum, has been successful to this day. The company had established itself in the Indian market as a “re-roller”, i.e., as a producer and processing company of cold strip. As part of a strategic backward integration, Bhushan Power & Steel invested in a CSP® plant which was started up in 2008. On account of the relatively low heat size (90 t), the short metallurgical length of the caster (6,340 mm with three segments) and the limitation to five finishing stands and one coiler, the investment cost could be kept low. With its maximum strip width of 1,300 mm the plant is adapted to the capabilities of the company’s own cold rolling mills. Meanwhile Bhushan Power & Steel has placed an order for the addition of a second casting strand, a sixth finishing stand and a second coiler to increase production and to reduce the final strip thickness.

Thin-strip production

The process-specific benefits of CSP® were first used mainly for the production of thin strip. The background to the production of thin (<1.5 mm) and ultra-thin (<1.0 mm) strip was the idea of substituting cold strip by hot strip and thus attaining significant cost advantages. At the end of the 1990s therefore, it was generally assumed that there would be a rising demand for thin strip [5].

The first steps in this area were undertaken at Hylsa (today Ternium Hylsa) in 1995. Practice showed that in order to attain these final gauges it was necessary to adapt the automation with a view to achieving full utilization of the efficiency of CSP® technology. Besides the modification of the drafting pattern, it was necessary above all to have an extended shape and flatness model, a high-speed gauge control system and a high-precision mass-flow and tension control system with optimized loopers. In addition, systems for roll-gap lubrication were installed for reduction of the roll force and the roll wear. With these facilities, a minimum final gauge of 0.91 mm could be attained at Ternium Hylsa. The process stability was enhanced further by the development of the differential tension looper and by the automatic levelling control based on this [6].

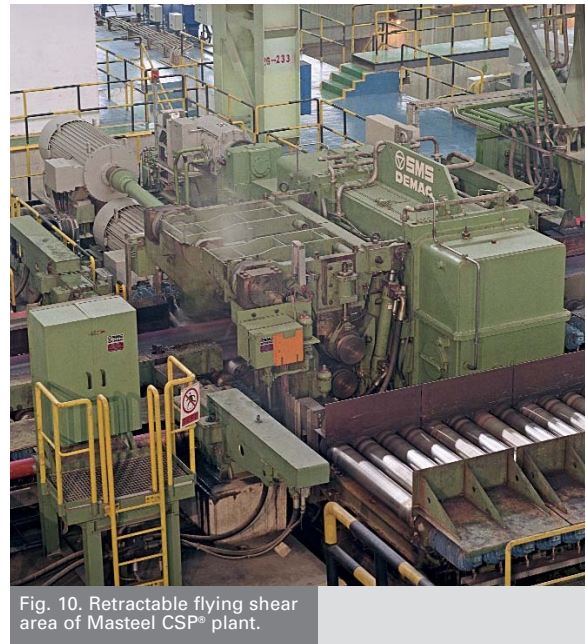


Fig. 10. Retractable flying shear area of Masteel CSP® plant.

The critical moment in the manufacture of thin strip continued to be the threading-in and tailing-out of the strip in the finishing mill. In order to achieve higher operational reliability, SMS Siemag developed semi-endless rolling. This has been successfully implemented at Masteel and Lysteel. In semi-endless rolling, an extra-long thin slab of 270 m and more is cast and rolled down in one operation. Rolling of this slab is started at an uncritical strip gauge. This allows the threading process to be reliably controlled. During rolling, the roll gaps are closed in order to produce ultra-thin finished-strip gauges. Upstream of the coiler, the strip is cut into individual coils. This makes it possible to produce ultra-thin strip almost risk-free.

Plants for semi-endless rolling were set up at Masteel (2003) and Lysteel (2004). The only difference in plant configuration as compared to the CSP® basic concept was the special-type high-speed shear, **figure 10**, which at strip speeds of up to 20 m/s is capable of splitting the strip into single coils and a special pinch roll unit with an adapted switch that allows a quick change from one downcoiler to the next. Using this system, Lysteel reliably produced strips in a gauge of 0.77 mm.

The commissioning of such facilities coincided with the start of the Chinese steel boom. The enormous demand arising from this meant that the firms were



Fig. 11. Casting machine at ThyssenKrupp Steel Europe. In this CSP® plant, both casting strands are supplied by a common tundish.

no longer obliged to specialize and the possibilities for production of thin strips were therefore utilized only to a small extent. On the other hand, around 50% of the total production of EZDK's (formerly ANSDK) CSP® plant covers a thickness range between 1.0 and 2.0 mm, and this Egyptian company has been successful in the market for one decade. In view of the changes now occurring on the market there is a likelihood that the niche product "thin strip" can regain its importance.

High-quality steel grades

Although the owners of CSP® plants initially concentrated mainly on the production of hot strip from simple carbon steel grades, SMS Siemag already knew at an early stage that CSP®, on account of its homogeneous production conditions, was suitable for producing high-quality steel grades and for rolling materials that require an exact temperature control [7].

Pioneers in the production of high-quality steel on CSP® were ArcelorMittal Riverdale, USA, (former ACME) and ThyssenKrupp Steel Europe, Germany. When commissioning the CSP® plant in 1999, ThyssenKrupp Steel possessed four conventional hot strip mills. It was intended that the new CSP® facility

should take over part of the production of one of the conventional hot strip mills and should be employed above all for the production of advanced steel grades, figure 11.

During the initial years, ThyssenKrupp Steel chiefly produced mild steels. Through continuous improvement of the overall process and optimization of the upstream process stages, the range of steel grades was able to be strongly expanded and the portfolio shifted towards especially high value added products. Mild, unalloyed steels today represent less than half of the production. With a proportion of almost 30 %, non grain-oriented electric steel strip already holds second position. Further products are HSLA steels, quenched and tempered steel grades and high-strength packing band. Compared with the conventional route, these strips exhibit greater uniformity as regards microstructure, mechanical properties and dimensional accuracy [8].

ArcelorMittal is making use of its CSP® facilities in a similar manner. In Bilbao, Spain, for example, not only thin strip up to 1.0 mm thickness but above all high-strength steels, pipe grades (up to X70), steel for pressure purposes and dual-phase steels are being produced.

The specialization of CSP® facilities on certain high-quality steel grades makes it possible to optimize the overall production in a manner that does justice to all of the different plants within a company group. These grades are more difficult to roll on conventional hot strip mills and they therefore restrict the productivity of these mills. When these grades are transferred to the CSP® line, the conventional facilities are able to utilize their strengths to the full as regards productivity. This results in increased overall yield of the facilities in the group.

This strategy is being employed increasingly by established steel producers. For example, Wuhan Iron & Steel (WISCO) is one of China's largest steel producers and intends to use its CSP® plant which went into operation in February 2009 mainly for producing Si grades. To guarantee a particularly high product quality, a number of novel features were introduced there. With a metallurgical length of 10.3 m and five segments, the caster is the longest made so far. It thus provides optimal support to the casting strand while allowing a high production rate even for large slab thicknesses. To remove the strongly adhering, sticky scale in Si grades, the plant has a rotating high-pressure descaler arranged upstream the pendulum shears in the entry section of the roller hearth furnaces [9].

Further DEVELOPMENTS OF CSP® CONCEPT

20 years after the introduction of the CSP® technology, SMS Siemag's reference list includes a total of 28 plants and reflects the large variety of CSP® plant users. However, to be able to offer customers an even higher productivity and flexibility, the CSP® idea is being continually developed further.

3-strand CSP® plant. An important milestone in the development of CSP® will be the commissioning of the first 3-strand plant at Essar Steel in India, **figure 12**. This plant will first start production in 2010 as a 2-strand plant with a capacity of 2.5 million t/a.

By adding a third casting strand, the annual capacity will then in 2011 rise to around 3.4 million t and thus be in the range of a conventional compact-type hot strip mill. Retrofitting a third strand is basically possible also in already existing plants.

CSP® facility with a parallel thick-slab line. An alternative concept is the combination of a single-strand CSP® facility with a conventional roughing train. In the single-strand roughing train thick slabs are reduced down to the typical thin-slab gauges of 50 to 70 mm

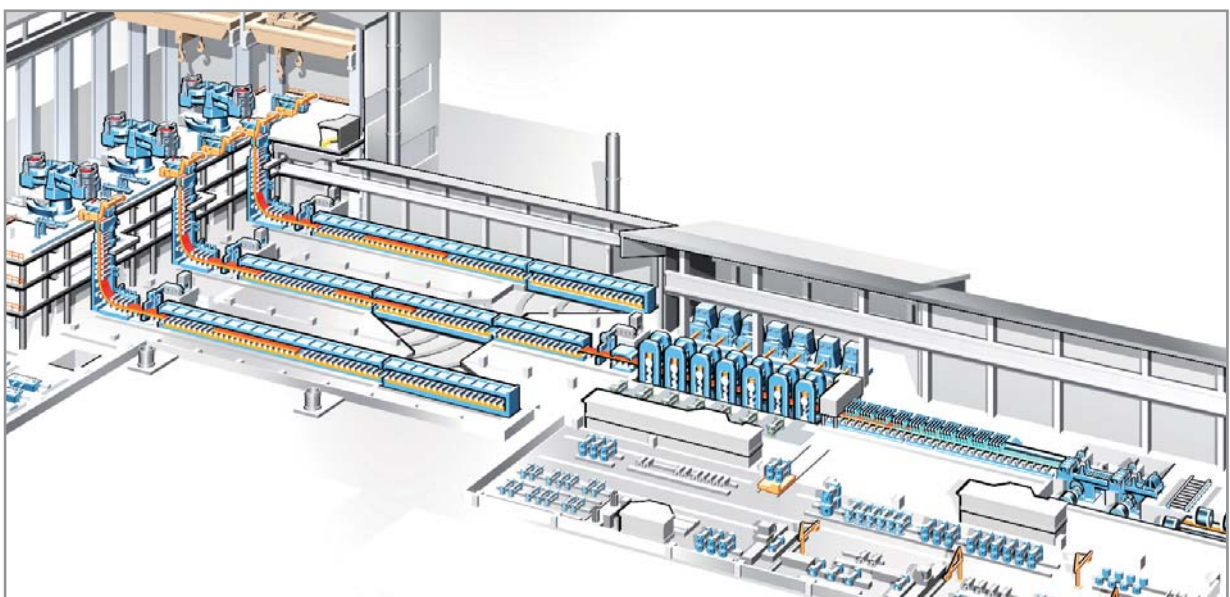


Fig. 12. Layout of the 3-strand CSP® plant at Essar Steel.

and are then fed to the CSP® line via a ferry and rolled down in the finishing mill. The extension makes it possible to produce steel grades and final dimensions which, due to process considerations, can be produced on CSP® facilities only to a limited extent.

A typical product group here are stainless steels that place extremely high demands on the surface quality. The combination of a thin-slab and a thick-slab line, **figure 13**, is therefore an attractive concept for those users who wish to cover the entire hot-strip product spectrum with all grades and dimensions by means of one single plant without having to forego the advantages of CSP® technology at the same time.

For the first time, SMS Siemag is implementing such a concept at G Steel in Thailand. Here, an existing casting-rolling plant is being extended by means of a single-stand reversing roughing mill. The new facilities will go into operation in 2011.

Batch/endless concept. The concept of endless rolling has been a recurring topic of interest among experts for decades. The main advantage of continuous operation is seen to be the uniform process conditions and the accordingly constant levels of product quality over the entire length of the strip. Threading-in

and tailing-out are no longer required, the process therefore takes place in a very stable manner and a particularly high yield becomes possible.

The endless concepts at present under discussion are characterised, furthermore, by a particularly compact plant layout. The extremely small plant length is achieved by inductive heating of the thin slab.

The superficial benefits of a compact endless facility have to be balanced against the enormous challenges posed by the plant operation. High casting speeds are necessary in order to ensure a sufficiently large mass flow in the plant for attaining the quality parameters of the products. These high casting speeds are today only attainable for simple steel grades (LC steels). It is also questionable whether continuous operation offers sufficiently strong advantages to justify the operational difficulties beyond thin-strip production.

The compact layout of the endless facility is achieved through the deletion of the tunnel furnace. There is hence no longer a buffer between the caster and rolling mill, so that for each roll change chopping of the thin slab must be accepted or the entire process stopped. Moreover, the idea of adding another or sev-

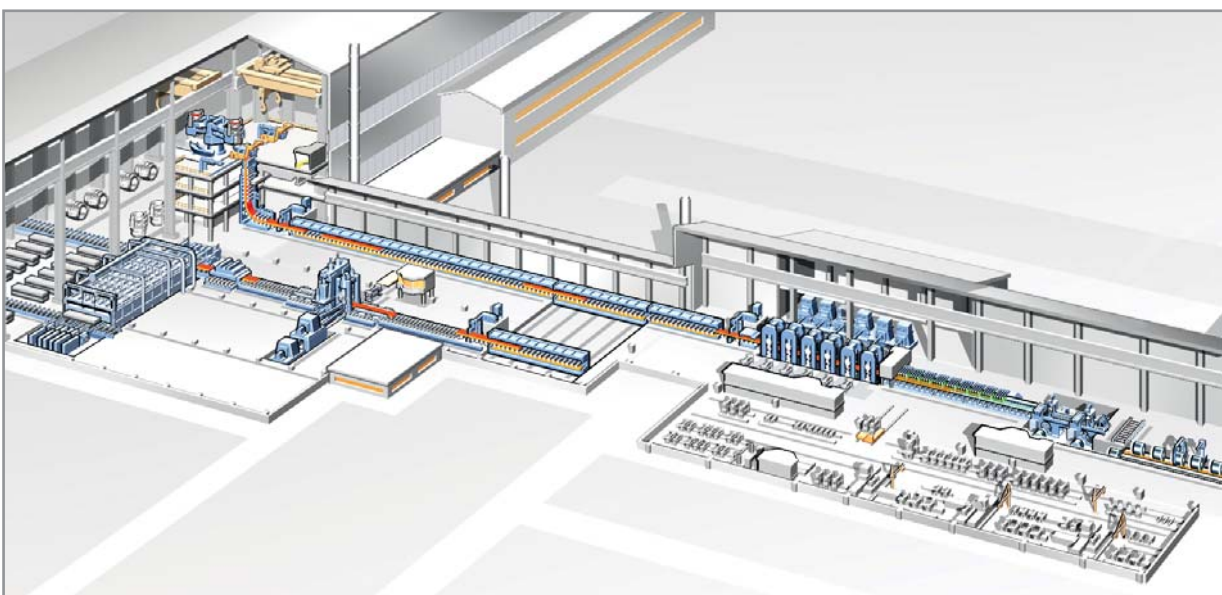


Fig. 13. Combined CSP® plant and thick-slab line.

eral casting strands to the facility must be given up. An intensified use of the rolling mill, the plant component with the highest investment volume, is thus impossible.

In view of these disadvantages of purely endless-type plants, SMS Siemag has developed a plant concept that allows both endless and batch operation. In this concept, a short tunnel furnace is attached to the caster. An inductive heater brings the thin slab up to rolling temperature. In addition, induction heating systems can be installed between the stands so as to enable the casting speed required for endless operation to be reduced.

Batch operation is practical during the start-up of the casting machine and the run-up of the casting speed. It also allows buffer capacities to be created so that rolls can be changed without losses of yield.

On finally comparing the energy consumption of the batch/endsless plant in endless operation with the classical CSP® facility, a higher consumption is obtained

for the batch/endsless plant, **figure 14**. Moreover, the induction heating system requires electricity, which is several times more expensive than e.g. natural gas used for the roller-hearth tunnel furnace.

SUMMARY and OUTLOOK

The CSP® success story that has been continuing for 20 years demonstrates that this plant concept is suitable for different requirements of the customers and of the market. Especially in view of the current market situation and the growing significance of environmental aspects, CSP® has the right answers to important questions relating to the future of the steel industry:

- high economic efficiency through reduced investment and production cost
- saving resources thanks to a low energy consumption
- high flexibility due to a wide range of products and hence the possibility of responding quickly to changing market conditions.

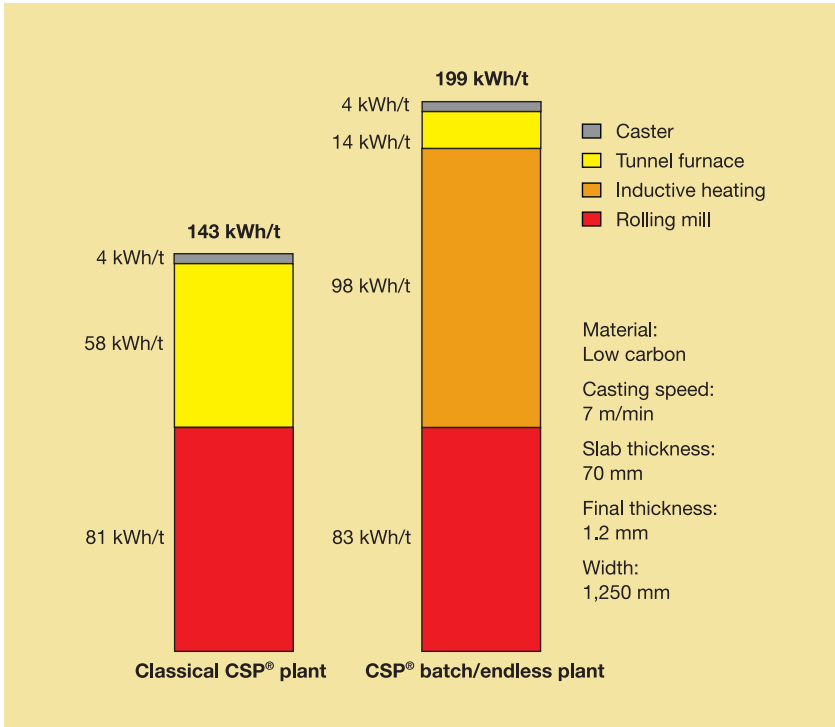
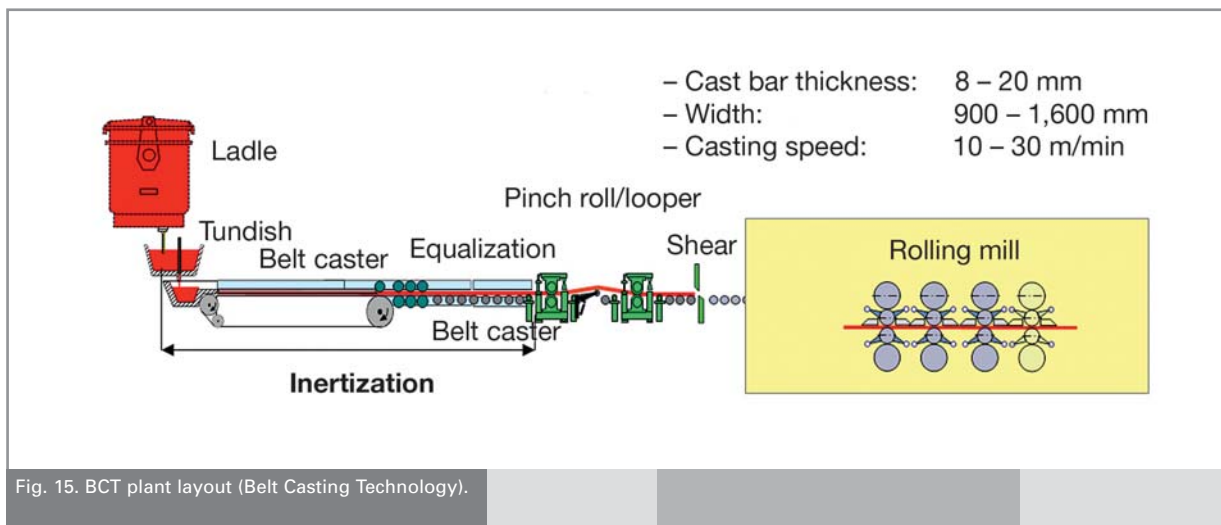


Fig. 14. Comparison of energy consumption of classical CSP® plant (typical furnace length) and CSP® batch/endsless plant in endless mode.



Also in the future, SMS Siemag will be working on the further development of CSP® technology. At the focal point of this are the further improvement of surface quality and the enhancement of productivity by increasing the maximum casting speed.

Furthermore, the range of castable steel grades is to be extended. In this connection SMS Siemag has developed, jointly with Salzgitter Flachstahl GmbH, the casting technology BCT(Belt Casting Technology) for the continuous casting of particularly crack-sensitive steel grades, **figure 15**.

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