CSP® TECHNOLOGY
INNOVATION MEETS EXPERIENCE

SYMPOSIUM
CHINA 2012
Welcome to SMS Siemag’s symposium on CSP® technology. With this event, we want to introduce you the latest, groundbreaking innovations in CSP® technology and discuss with you the future challenges of CSP® in the Chinese market.

Based on more than 20 years of leadership in thin slab casting and rolling, SMS Siemag has opened a new chapter in the development of CSP® technology. With additional technologies and components for casting, heating and rolling, CSP® offers extended possibilities and new tailor-made technological solutions.

As a reaction to rising energy prices, one focus of innovation is on the minimization of energy consumption. Due to intelligent further developments, energy consumption can be reduced to a minimum. With this result, CSP® remains the benchmark in energy efficiency. Also the energy consumption of existing CSP® plants can be reduced drastically with the new technology.

A wide product range has always been one of the major characteristics of CSP® technology. With new developments, CSP® plants are able to operate just as flexible as conventional hot strip mills and cover the complete product range from 0.8 millimeter low carbon to 20 millimeter API grades. Also a hybrid CSP® concept was developed combining endless operation for ultra-thin strip production and batch operation for all other products and final gages.

Innovations have also been realized in casting technology. To be able to increase production to more than 1.5 million t/year per strand, a VLB thin slab caster was added to the caster portfolio. The revolutionary Belt Casting Technology (BCT®) is a further technology leap in near-net-shape casting and is mainly designed for crack-critical steel grades.

A major recent development for the successful operation of CSP® plants was the integration of mechanics, media systems and electrical and automation systems under our responsibility. Today’s status of SMS Siemag as a system supplier is proven by the excellent start-up and performance results, for example, of the CSP® plants at Severstal Columbus (USA), Essar Steel and Tata Steel (both India).

SMS Siemag’s X-Cellize® service solutions are based on a global approach to support operators of metallurgical plants over the entire lifecycle of their plants. Especially in China, we continue to extend our service portfolio in order to support CSP® customers to face their challenges.

China has been playing an important role for CSP® technology for many years. In 2012, it has been exactly 15 years since Guangzhou Zhujiang Steel, Handan Iron & Steel and Baotou Iron & Steel ordered the first CSP® plants for China. With the combination of more than 20 years of experience and the new developments, CSP® technology will provide the Chinese steel industry with outstanding benefits also in the future. They prove that CSP® is the most economical, reliable and unlimited technology for the production of high-quality hot strip. We cordially invite you to our symposium to discover what this means for your goals.

Dieter Rosenthal
Member of the Managing Board of SMS Siemag
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The development of the CSP® technology coincided with the steel crises in the 1970s and 1980s, where many steel producers were forced to cut overcapacity. Against this background “near-net-shape” casting and direct rolling was widely discussed mainly with the focus on cutting investment and conversion costs. The technological breakthrough was achieved by SMS Siemag in October 1985 with the casting of the first thin slab of 50 millimeter thickness on a pilot plant. In 1989, Nucor was the first company to invest in the new technology. The prime focus of Nucor was on the profitability of the concept due to reduced investment and conversion costs. CSP® enabled Nucor and other flat steel start-ups to enter the market with clear-cut investments and definite cost benefits compared to integrated plants.

One major trend in the development of CSP® was the extension of the range of products in terms of final thicknesses and steel grades. The process-specific benefits of CSP® were first used mainly for the production of thin strip. Production of strip below 1.0 millimeter final thickness started already in 1995. Due to the uniform rolling conditions as a result of the almost constant temperature over width, length and thickness of the thin slab, CSP® proved to be especially suited for thin strip production. To obtain an even more stable rolling process for ultra-thin strip gages, the semi-endless process was developed and implemented for the first time in 2003 at Masteel’s CSP® plant. For a number of CSP® users, thin strip proved to be a successful niche product, some of them producing 30 percent of their annual production as thin and ultra-thin hot strip in gages of 1.2 millimeter and less. Already in the 1990ies, the expansion of the steel grades spectrum started. On account of its homogeneous process conditions, CSP® is perfectly suited for the production of high-quality steel grades and for rolling materials that require an exact temperature control. Today, the product range covers all the steel grades demanded by the market, in particular low-carbon IF and mild steel grades, medium- and high-carbon steels, HSLA and API pipe steels, stainless, acid and heat-resistant special steels, as well as Si-alloyed electrical steel grades.

Since its introduction, SMS Siemag continuously improved CSP® technology. Benchmarks showing the technical maturity of CSP® are for example casting speeds of more than 6.5 m/min in regular operation, casting sequences of up to 45 heats during a net casting time of more than 24 hours or a plant availability (“steel-in-mold-time”) above 80 percent in numerous plants. These excellent performance indicators are the results of the integration of mechanics, media systems and electrical and automation systems under one responsibility. Today, SMS Siemag supplies the complete CSP® technology from the caster and the tunnel furnace to the mill with mechanics, automation, electrics and services. This integrated expertise is a decisive factor for productivity, availability and product quality, or, in other words, for the success of a plant.
CSP® – the benchmark in energy efficiency.

High-strength, thick pipe grades are one focus of recent developments in CSP® technology.

Inductive heatings for flexible adaptation of thin slab temperature are part of the CSP® eco package.

The key for thin slab casting: The CSP® mold.

1 CSP® – A SUCCESSFUL TECHNOLOGY FOR START-UPS AND STEEL GIANTS

By 2012, 27 CSP® plants are in operation worldwide. Included are former newcomers in the flat steel market like Nucor or Bhushan Power & Steel (India), steel producers in up-and coming countries like Malaysia or Thailand to well established, integrated steel giants like ArcelorMittal, ThyssenKrupp Steel, Tata Steel or Wuhan Iron & Steel.

The Chinese market has been of special importance for CSP®. The expansion of the Chinese flat steel capacities started simultaneously with the supply of the first three Chinese CSP® plants to Guangzhou Zhujiang Steel, Handan Iron & Steel and Baotou Iron & Steel. Also a large number of innovations have been implemented in the Chinese CSP® plants as the semi-endless rolling at Masteel and Lysteel. And Juquan Iron & Steel was the first CSP® plant where SMS Siemag supplied also the complete electrics and automation. The CSP® plant of Wuhan Iron & Steel was the first with a strong focus on Si-grades.

NEW DEVELOPMENTS FOR THE FUTURE OF CSP®

Based on the successful CSP® technology, SMS Siemag has now made a new development step. The challenge was to offer customers even more possibilities regarding product capacity, product spectrum and energy efficiency without neglecting the strong points of CSP® technology such as low operating costs, high availability and yield, absolutely uniform product properties and a wide range of different steel grades. To fulfill this, new technologies and components in casting, heating and rolling area were added to the CSP® concept. This allows tailor-made technological solutions to be provided.

The new highlights of CSP® are:

- A production capacity up to 4 million t/year in two-strand operation. This is mainly made possible by increasing the casting thickness with a VLB (Vertical Liquid Bending) casting machine.
- The production of pipe grades (e.g. API X70) up to 20 milimeter thickness. Here, the key feature is the innovative CSP® Vario Mill which is characterized by a strong medium stand M1 and induction heating between M1 and F1. The Vario Mill was developed on the basis of the metallurgical necessities for the rolling of high-strength grades.
- A flexible hybrid plant concept for endless and batch operation. With this concept, endless operation can be applied for ultra-thin strip, whereas batch operation can be applied to all products and final gages which do not benefit from the endless casting and rolling mode.
- The reduction of energy consumption to a minimum due to the optimization of the process as well as the introduction of improved components with respect to energy consumption. These measures can also be applied to existing CSP® plants.

Due to the combination of a vast experience collected in more than 20 years of CSP® and the extension of the CSP® concept, SMS Siemag will also in the future take the leadership in thin slab casting and rolling technology.
CSP® PLANTS IN CHINA

China has been playing an important role for CSP® technology for many years. In 2012, it has been exactly 15 years since the first CSP® plants for China were ordered. In Chinese CSP® plants, also a number of innovations have been implemented for the first time and remarkable operational results were achieved.

Guangzhou Zhujiang Steel – China’s First
China’s first CSP® facility went into operation at Guangzhou Zhujiang Steel in 1999. The order for the plant had been placed in 1997 as part of a package with the facilities for Handan and Baotou. This investment in CSP® was a milestone in the rapid expansion of capacities for flat products in China that took place since the beginning of this century. The CSP® plant at Guangzhou Zhujiang Steel is the only one in China to have an electric steelmaking plant installed upstream. In 2006, the first CSP® casting strand was retrofitted with LCR3. The second casting strand had already been equipped with LCR3, and also with an electromagnetic brake (EMBr), at the time of its commissioning in 2003.

Handan Iron & Steel – CSP® Mill with Roughing Stand
The special feature of the CSP® facility of Handan Iron & Steel is the roughing stand. Prior to finish-rolling, it reduces the thin slab to a thickness of approx. 35 millimeter in a single pass. Handan Iron & Steel has utilized CSP® to enter the field of hot strip production. The CSP® works commenced production in 1999 as a single-strand facility. The second casting strand followed in 2003, along with the extension of the rolling mill. In addition, a conventional hot strip mill supplied by SMS Siemag has been in operation at the Handan location since 2008. For the future, the two companies agreed upon a strategic cooperation in the areas of plant engineering, spare parts and service in order to further strengthen the competitiveness of Handan Iron & Steel.

Baotou Iron & Steel – Highly Productive
With an annual capacity of around 3 million tons, Baotou Iron & Steel is one of the world’s most productive CSP® facilities. This high production was made possible by the very efficient organization of the entire production sequences and by various modernization measures. The extension of the casting strand from three to four segments in 2005 enabled higher casting speeds and thus a greater throughput. The expansion of the CSP® rolling mill by a seventh finishing stand and the modernization of the intermediate stand area by installing equipment for roll-gap lubrication likewise contributed to the increase in production and, furthermore, to an improvement in strip quality.

Maanshan Iron & Steel – Semi-Endless Rolling
Masteel was the first CSP® facility designed for semi-endless rolling for the production of ultra-thin strips. In semi-endless rolling, the strip is threaded into the mill stands at a non-critical gage. The roll gap is then closed during rolling and the strip gage thus reduced to the desired thin strip dimension. Upstream of the coilers, a special high-speed shear cuts the strip into individual coil lengths at strip speeds of up to 20 m/s.

For Masteel, the CSP® facility was the entry into the production of flat steel products. Since 2007 the company also possesses a conventional hot strip mill supplied by SMS Siemag and thus has a total capacity of 7.5 million tons of flat products. In August 2009, the dynamic thickness reduction LCR
1 The key for semi-endless rolling: High-speed shear at Masteel.
2 Jisco was the first plant with complete electrics and automation from SMS Siemag.
3 The first Chinese CSP® coil at Guangzhou Zhujiang Steel.
4 Dedicated to advanced steel grades: Wuhan Iron & Steel.
5 The only one with one roughing stand: Handan Iron & Steel.

plus was put into operation on the casting machine. Masteel is therefore the first plant on which a thickness reduction of 30 millimeter is possible for the partially solidified slabs.

LIANYUAN IRON & STEEL – MINIMUM THICKNESS
The CSP® plant at Lianyuan Iron & Steel has obtained the record for the strip with the thinnest final gage on a CSP® facility. The strip with a gage of 0.77 millimeter was rolled using the semi-endless process.

For Lysteel, as for the majority of Chinese plant owners, the CSP® facility represented the company’s entry into the production of flat products. Since then, Lysteel has continuously expanded the range of products on its CSP® facility. Today, this range extends from extremely mild deep-drawing grades to high-carbon steels and also includes pipe grades (up to X65) and silicon steel grades.

JIUQUAN IRON & STEEL – OPTIMIZED WITH PLUG & WORK
The CSP® plant at Jiuquan Iron & Steel (Jisco) was the first facility for which SMS Siemag, as the system supplier, provided the entire plant technology including the complete electrical and automation system. The optimized interplay of the systems enables the plant to achieve strip gages of 0.8 millimeter with only six mill stands in batch rolling mode. Prior to commissioning of the plant, SMS Siemag had tested and optimized the electrical and automation system by using the Plug & Work method. During this, the software and hardware of the entire automation system were tested against real-time simulations.

Plug & Work made it possible to optimize all sequences and gave the Jisco operating personnel the opportunity to become familiar with the plant already before commissioning. This resulted in a rapid and stable run-up and the attainment of full production capacity already after eight months.

WUHAN IRON & STEEL – DEDICATED TO ADVANCED STEEL GRADES
Wuhan Iron & Steel (Wisco) is one of China’s largest steel-makers and, since March 2009, operates a CSP® facility in addition to its three conventional hot strip mills. On the CSP® plant, Wisco concentrates the manufacture of strips made from high-quality steel grades such as electric-sheet. The favorable process conditions make CSP® ideally suitable for the production of materials which require precise temperature control.

With a metallurgical length of 10,305 millimeter, the CSP® casters at Wisco are the longest of all CSP® plants and allow high production also of large slab thicknesses. The plant also possesses a rotating high-pressure descaling system in the exit section of the caster so as to enable the strongly adhering sticky scale to be removed more efficiently on strips made from Si grades. The seven-stand rolling mill makes possible high degrees of deformation and thus small final gages also for wide strips.
FOR MORE THAN TWO DECADES, CSP® HAS BEEN THE MOST SUCCESSFUL THIN-SLAB CONCEPT WORLDWIDE. RECENTLY, EXPANDED MARKET DEMANDS HAVE LED TO NEW DEVELOPMENTS. TODAY, CSP® OFFERS A GREATER RANGE OF POSSIBILITIES REGARDING PRODUCTION CAPACITY AND PRODUCT MIX – ESPECIALLY FOR HIGH-STRENGTH GRADES. IN ADDITION, ENERGY CONSUMPTION IS REDUCED DRASTICALLY, AND CSP® IS THEREFORE THE MOST ECONOMICAL PLANT CONCEPT FOR THE PRODUCTION OF HIGH-QUALITY HOT STRIP.

The new developments were made without forfeiting the strong points of CSP® such as low operating costs, high availability and yield, absolutely uniform product properties and a wide range of different steel grades. To fulfill this, new components in the casting, heating and rolling areas were added to the CSP® concept. This allows tailor-made technological solutions to be provided.

CASTING MACHINE CONCEPTS FOR A WIDE CAPACITY RANGE

The key to boosting the annual capacity and increasing final strip thicknesses is the casting machine. So far VSB (Vertical Solid Bending) casting machines have been used. These casters, which operate with a solid core in the bending zone, achieve production volumes of about 1.5 million tons per year per strand. Typical features of VSB casters are symmetrical strand cooling and solidification, short mold and segment change times and ease of maintenance.

Production is raised by increasing the casting thickness. This requires a greater metallurgical length in the casting machine, which can be economically achieved by the use of a VLB (Vertical Liquid Bending) casting machine. VLB-type casters operate with a liquid core in the bending and straightening zones. Production volumes of 2.0 million tons per year per strand are possible.

ROLLING MILL CONCEPTS FOR THE PRODUCTION OF PIPE GRADES

A major development focus was on the production of pipe grades. High-strength pipe grades with excellent toughness properties up to a thickness of more than 12.7 millimeter can already be manufactured from slabs of thicknesses between 50 and 60 millimeter on the compact CSP® rolling mill. With the new Vario Mill, the final thickness of e.g. API X70 grade can be increased to 20 millimeter.

For the production of high-strength pipe steel strip, it is essential that the hot strip features an entirely homogeneous, fine-grained microstructure. By suitably setting the pass reductions and temperatures, the CSP® Vario Mill guarantees that the microstructure completely recrystallizes at least two times. An induction heating system is installed in the gap between M1 and F1. The temperature of the strip and its transfer time between M1 and F1 are controlled such that complete recrystallization will take place after the two stands. This technique enables the production of thicker hot strip with higher strengths and at the same time superior toughness properties. In comparison to concepts with one or two decoupled roughing stands, there is no premature precipitation of microalloying elements or substantial grain growth. Thus, higher microalloy contents can be attained, enabling hot strip of higher strength classes to be produced. Thanks to the complete elimination of non-homogeneities originating from the cast structure, thicker strip can be obtained from slabs of a given thickness.
This result was proven by intensive scientific research. The microstructure of an API grade X70 sample produced on the Vario Mill consists of uniformly recrystallized grains and is free from non-homogeneous constituents. The grain size distribution shows a scatter band closely grouped around the mean grain size.

**CSP® ENDLESS ROLLING**

For customers aiming at a production with a very high proportion (above 50 percent) of thin and ultra-thin hot strip below 1.2 millimeter thickness, endless mode of operation can be added. To achieve acceptable final rolling temperatures in endless operation, inductive reheating is required in the rolling mill. Consequently, for energy-related reasons, batch operation should be applied to all products and final gages which do not benefit from the endless casting and rolling mode. The main components of this plant concept are a caster of VLB type for high production, a Core Reduction (CR) stand, the Vario Mill including inductive heating and a high-speed shear.

**ENERGY EFFICIENCY**

SMS Siemag has further developed CSP® with respect to energy efficiency and reduced consumption to a minimum. This ambitious goal was realized by analyzing the complete production process as well as all components.

Concerning the process, the temperature of the thin slab is no longer increased up to a temperature which is ideal for all grades and dimensions but is kept on a lower level close to the temperature after casting. At this lower temperature, the overwhelming proportion of grades and dimensions can be rolled without constraints in process stability and product quality. This leads to drastic savings in energy. For certain steel grades the total furnace temperature can always be raised according to metallurgical necessities.

The reduction of the tunnel furnace temperature goes together with the installation of inductive heaters upstream of the rolling mill. When rolling grades or dimensions requiring a higher rolling mill entry temperature, this can be set precisely by means of inductive heaters. With this solution, the large product spectrum typical of CSP® and a reduction of energy consumption can be realized at the same time.

At the level of plant components, the largest energy savings can be realized by installation of dry-type furnace rollers. With new high-temperature alloy furnace rollers from SMS Siemag, the heat extraction from the tunnel furnace can be reduced by 50 percent compared to water-cooled rollers. Further measures for reducing energy losses are the installation of a rotary descaler in the entry of the mill and the reduction of stand distance in the CSP® mill.

With the installation of dry-type furnace rollers, a rotary descaler and the reduction of the tunnel furnace temperature in combination with the inductive heating, parts of this concept can also be applied to existing CSP® plants. This modernization concept will be realized for the first time at the Nucor Steel plant at Berkeley (USA).
The goal was ambitious: Reducing the energy consumption to a minimum without neglecting the advantages of CSP® such as excellent product quality, large product mix, flexibility and the possibility to extend the capacity step-by-step. Therefore, the complete CSP® process as well as all components were thoroughly analyzed.

ENERGY SAVING ACHIEVED WITH FLEXIBLE TEMPERATURE CONTROL
Subsequently to the casting process, the thin slab is transferred through the tunnel furnace and heated up to a certain temperature before it exits the furnace and enters the mill. Due to a relatively slow response of the tunnel furnace temperature, its set-point is constantly adjusted to a necessary maximum, in order to fulfill the requirements for all steel grades and thin slab dimensions.

Though, most of the steel grades and thin slab dimensions do not require such a high tunnel furnace temperature and can be rolled without constraints in process stability and product quality at lower temperatures. As part of the CSP® eco package, the tunnel furnace temperature is kept almost on casting temperature level. This saves energy significantly. In case the thin slab needs to be heated up to a higher rolling mill entry temperature, this is precisely realized by an inductive heating unit, located directly at the end of the tunnel furnace and enabling a temperature increase of up to 50 °C. With this solution, both the large and typical CSP® product spectrum as well as a significant reduction of energy consumption can be realized at the same time. For microalloyed steel grades requiring a higher thin slab temperature due to metallurgical necessities, the total tunnel furnace temperature can also be increased.

ENERGY SAVING ACHIEVED WITH ENERGY-EFFICIENT COMPONENTS
Related to all thin slab production processes, the tunnel furnace is obviously the main energy consumer when compared to caster and mill. So, the biggest energy savings can be achieved by optimizing its components. In a tunnel furnace thin slabs are transported by furnace rollers. Generally, there are two different types of furnace rollers existing: Water-cooled and dry furnace rollers. Companies like e.g. Bricmont, Thermocast, FGF, Ferroman, Butting or Duraloy offer various types of each furnace roller, looking back on a long time of experience.

As part of the CSP® eco package, SMS Siemag further developed both water-cooled and dry furnace rollers. Using special high temperature resistant fiber wool instead of concrete as
A high-pressure rotary descaler reduces the temperature drop before rolling.

CSP® eco package with inductive heating unit and water rotary descaler can also be implemented in existing plants.

SMS Siemag’s water-cooled (left) and dry furnace rollers (right)

refractory material for the water-cooled SMS Siemag furnace rollers, the heating up of the cooling water can be reduced significantly without influencing the required cooling of the materials. So, the total energy consumption of the complete tunnel furnace can be reduced by 20 percent, considering all other heat losses. The dry furnace rollers are made of various high-temperature alloys. They do not need any water-cooling. SMS Siemag uses patented high-temperature alloys for the dry furnace rollers allowing an operation up to 1,200 °C. Such a high temperature is necessary e.g. for the production of microalloyed steel grades. A tunnel furnace operating with dry SMS Siemag furnace rollers instead of customary water-cooled furnace rollers can reduce its total energy consumption by 50 percent, considering all other heat losses. As part of the CSP® eco package, innovative components can also be implemented downstream of the tunnel furnace to reduce temperature losses. At the entry of the CSP® mill, a high-pressure rotary descaler can be installed in place of the conventional descaler. The rotary descaler achieves a very effective cleaning of the thin slab surface by using less water. This results in a significantly lower temperature drop of the thin slab before it enters the CSP® mill.

In the CSP® mill, the distances between the stands can be reduced. This saves energy again, because the temperature drop between the stands is lower, resulting in lower roll forces. Taking all these measures into account, the energy consumption can be reduced significantly. Thus, CSP® remains the standard in energy efficiency.

MODERNIZATION OF EXISTING PLANTS
Most of the above introduced concepts can be applied to existing CSP® plants. A significant reduction of energy consumption can be realized by installing optimized tunnel furnace rollers, a rotary descaler and the flexible tunnel furnace temperature control combined with the inductive heating unit. For the first time, this complete package will be realized at the Nucor Steel CSP® plant at Berkeley (USA).
PRODUCT RANGE
FROM 0.8 MM LOW CARBON TO 20 MM API GRADES WITH ONE TECHNOLOGY

THE LARGE PRODUCT MIX INCLUDING THIN AND ULTRA-THIN STRIP HAS ALWAYS BEEN ONE OF THE MAJOR CHARACTERISTICS OF CSP® TECHNOLOGY. FOLLOWING RECENT MARKET DEMAND FOR THICKER GAGE API STEEL GRADES, SMS SIEMAG ADDED NEW COMPONENTS TO THE PROVEN CSP® CONCEPT. THE KEY FEATURE FOR THE PRODUCTION OF THICKER GAGE API LINE PIPE GRADES HAVING HIGH STRENGTH AND EXCELLENT TOUGHNESS PROPERTY IS THE INNOVATIVE VARIO MILL.

CSP® – THE SYNONYM FOR A LARGE PRODUCT MIX

Today, CSP® technology is a standard technology for hot strip production. Since the introduction in 1989, SMS Siemag has continuously improved the CSP® technology which is amongst the most important processes for the manufacture of high-quality flat steel. By mid-2012, a total of 27 plants have gone into production.

From the very beginning a wide product range has always been one of the major characteristics of CSP® technology. On account of the homogeneous production conditions, CSP® is perfectly suited for the production of high-quality steel grades and for rolling materials that require exact temperature control. CSP® plants cover all relevant steel grades demanded by the market, in particular low-, medium- and high-carbon steel grades comprising IF-, HSLA-, API-, Multi-phase- and Si-alloyed electrical steel grades.

One additional prime quality of CSP® is the production of thin and ultra-thin strip that is due to the absolutely stable rolling process. The reason for this is to be found in the homogeneous temperature along the width, thickness and length of the thin slab. The resulting uniform rolling conditions ensure homogeneous structural and mechanical properties all along the strip. To date, more than 15 million tons of strip below 1.5 millimeter thickness have been produced by CSP®.

Also on the other end of the strip thickness spectrum, the CSP® product mix was considerably enlarged since the mid 1990ies. As a result of intensive research by SMS Siemag and close cooperation with its customers, final thickness and strength of API line pipe steel grades were step-by-step increased while keeping excellent toughness properties. Today more than 1.5 million tons of API pipe steel grades in thicknesses of more than 12.7 millimeter have been produced on CSP® plants.

INNOVATIVE VARIO MILL

Market demands considerably changed in the last couple of years. Among these, final strip thickness from 0.8 millimeter low carbon up to 20 millimeter API line pipe grades has become a widespread requirement. The only way to achieve an optimum combination of strength and toughness is an entirely homogeneous, fine-grained microstructure of the hot rolled strip. Therefore special attention has to be paid to chemical composition and production technology. Microalloyed HSLA and API line pipe grades are typically produced by two step thermomechanical hot rolling starting in the recrystallizing temperature area and finish rolling below austenite recrystallization temperature. Direct rolling of thin slabs as in the CSP® process starts from a highly inhomogeneous coarse-grained as-cast structure. To obtain optimum strength and toughness property combinations, it is most important to transform this as-cast structure into a homogeneous fine-grained recrystallized austenite microstructure after the first two or three mill stands. The reason being that structural heterogeneities as single coarse grains will be inherited in the final strip’s microstructure and will deteriorate toughness. Toughness is also closely related to the total thickness reduction during hot rolling. Raising the thin slab thickness as well as eliminating structural heterogeneities in
1 Core Reduction (CR) stand in front of the roller hearth furnace for thin and ultra-thin strip production.
2 Temperature control during isothermal rolling on a CSP® Vario Mill and fine grained microstructure at indicated sampling point.
3 The CSP® Vario Mill – key technology for thick gage API fine pipe steel.

The hot strip will help to increase the upper limits for thicker gages and higher strength levels. Common concepts as 5 to 7 stand compact mill or 4 to 6 stand finishing mill plus one or two rougher stands do not meet all these requirements. Based on metallurgical considerations, SMS Siemag further developed the successful CSP® concept by adding new components in the casting, heating and rolling areas to meet these requirements while keeping the strong points of CSP® technology. The key feature for the production of API grades in larger thicknesses is the innovative CSP® Vario Mill allowing isothermal rolling in the first stands of the finishing mill. It is composed of a powerful twin drive M1 medium stand separated by about 11 m from the first finishing stand F1. A pre-leveler to straighten the transfer bar head end as well as an inductive heater for temperature adjustment prior to F1 can be arranged in this space. The temperature and interpass time in between M1 and F1 are adjusted to trigger complete recrystallization after both mill stands. This way after F1 a completely homogeneous, fine-grained microstructure is achieved. When compared to concepts having one or two decoupled roughing stands, there is no premature precipitation of microalloying elements or substantial grain growth. Thanks to the complete elimination of non-homogeneities originating from the cast structure, thicker hot strip having an optimum combination of strength and toughness can be produced. In addition, isothermal rolling in the first stands of the finishing mill gives the possibility to rise the microalloy content, especially that of niobium. Thus, hot strip of higher strength classes can be achieved.

A PLANT CONCEPT FOR 0.8 MM TO 20 MM
The Vario Mill can be combined to a caster of VSB (Vertical Solid Bending) or VLB (Vertical Liquid Bending) type. Thanks to a larger thin slab thickness, a VLB caster will help to increase hot strip thickness. Thus 20 millimeter thick API grade hot strip having excellent combination of strength and toughness can be produced from 100 millimeter thin slab. Because of the typical process characteristics mentioned above, the Vario Mill concept is also well suited for the production of thin and ultra-thin hot strip. By arranging a CR (Core Reduction) stand in the area between exit caster and pendulum shear in front of the roller-hearth furnace, up to 120 millimeter thick slabs can be reduced to 40 – 60 millimeter thickness. This way, optimum slab thickness and strip end shape is obtained, offering a reliable and stable rolling process when rolling thin hot strip gage. The CR stand enables slab thickness reduction without any loss in productivity as it would happen when applying liquid core reduction (LCR) in the caster. Adding a flying shear and a second coiler even allows endless rolling of strip thickness below 1 millimeter.
The introduction of CSP® thin slab technology enabled the production of thin and ultra-thin hot strip, which is also suitable for the substitution of cold strip. Ternium México (formerly Hylsa) has been producing finished strip in gages below 1.0 millimeter since 1995. Strips with a gage of 0.8 millimeter have been produced in batch operation by various manufacturers, such as Wuhan Iron and Steel in China and others. Up to today the totalled global production of CSP® thin and ultra-thin hot band (that is defined as strip thickness < 1.5 millimeter) exceeds 15 million metric tons. At Essar Steel (India) sequences of more than 30 strips in final gages of ≤ 1.1 millimeter were rolled as early as in the fourth month after commissioning. The optimum final rolling temperature was observed for all strips.

**PRODUCTION OF ULTRA-THIN STRIP**

The distinguishing feature of today’s innovative CSP® concept is its modular structure with additional components for the casting machine and the rolling mill. This allows tailor-made technological overall solutions to be provided. The Vario Mill is not only designed for the production of thick, high-strength strips but also makes it possible to manufacture the wide product range typical of CSP®, including thin strip in a gage of ≤ 1.0 millimeter even from a thicker slab. By arranging a CR (Core Reduction) stand in the area between exit caster and pendulum shear in front of the roller-hearth furnace, up to 100 millimeter thick slabs can be reduced to 40 – 60 millimeter thickness and subsequently shear cut. This way, optimum slab thickness and strip end shape is obtained, which guarantees a reliable and stable rolling process for thin hot strip gages. The CR stand enables slab thickness reduction without any loss in productivity as it would happen when applying Liquid Core Reduction in the caster.

**CONCEPT FOR ENDLESS PLUS BATCH MODE**

Today some CSP® plants are producing 30 percent of their annual production as thin and ultra-thin hot strip in gages of 1.2 millimeter and less. Customers that are aiming for an even higher share of hot strip below 1.0 millimeter strip gage, sometimes fancy the endless mode as an interesting alternative. Since threading-in and tailing-out are no longer required, rolling instabilities at the strip head and tail ends can be avoided when rolling thin strip gages while at the same time the risk of cobbles may be reduced. CSP® also includes highly efficient endless concepts for the production of ultra-thin strip, which enable the batch mode in addition to endless operation and thus offer the customer a high degree of flexibility. The configuration with Vario Mill is able to produce high-strength API line pipe grades in final thicknesses up to 20 millimeter as well as thin and ultra-thin hot strip. The latter one can be processed by endless but also by batch rolling. The concept accordingly allows endless plus batch mode operations.
The high-speed shear was for the first time implemented at Maanshan Iron & Steel in 2003.

Thin-strip rolling campaigns at Essar Steel, August 19th 2011.

Plant concept with Vario Mill for the production of thin strip in batch and endless mode.

For endless operation, the caster is normally a bow-type one (VLB, Vertical Liquid Bending) in order to achieve a high mass flow. Directly after leaving the caster, the slab is reshaped in a CR (Core Reduction) stand. The slab subsequently runs through a short tunnel furnace. This furnace is designed in a way providing sufficient buffer time, as to make batch operation and work-roll changing possible. Upstream of the coilers, the proven high-speed shear cuts the endless strip into single-coil lengths.

However, an endless rolling facility can only be operated economically when the costs for endless operation do not outweigh the advantages and savings thereby achieved. In the endless process the rolling speeds are approx. 30 percent lower than for batch operation due to the coupling with the casting process. To achieve acceptable final rolling temperatures, inductive reheating is therefore required in the rolling mill. Consequently, for energy-related reasons, batch operation is always preferable to endless mode. For high-quality steel grades the batch mode is generally required for metallurgical and economic reasons. In view of these considerations, CSP® concepts always allow the batch mode in addition to endless operation. This offers the customer the necessary flexibility in his operational sequences, as well as a wide range of products.

### CSP® Plant Country Minimum Hot Band Thickness in mm

<table>
<thead>
<tr>
<th>CSP® Plant</th>
<th>Country</th>
<th>Minimum Hot Band Thickness in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severstal Columbus</td>
<td>USA</td>
<td>1.00</td>
</tr>
<tr>
<td>Nucor Hickman</td>
<td>USA</td>
<td>1.00</td>
</tr>
<tr>
<td>SDI</td>
<td>USA</td>
<td>1.05</td>
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<tr>
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<td>India</td>
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</tr>
<tr>
<td>NSM</td>
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<tr>
<td>Essar Steel</td>
<td>India</td>
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</tr>
</tbody>
</table>

Table 1 Examples for CSP® hot strip minimum thickness achieved.
CSP® technology (Compact Strip Production), combining thin slab casting with direct hot rolling, has become a standard technology for hot strip production. Since its introduction in 1989, SMS Siemag has continuously improved its CSP® technology, which is among the most important processes for the manufacture of high-quality flat steel. By mid-2012, as many as 27 plants have gone into production.

The main characteristics of CSP® are:
- Minimized number of process steps
- Minimum investment and processing costs
- Environmentally friendly technology with low energy consumption
- Excellent product quality and production performance
- Large product mix covering all relevant steel grades demanded by the market.

CSP® IN INDIA

Four CSP® plants are located in India: JSW Ispat, Bhushan Power & Steel, Essar Steel India and Tata Steel. The total nominal capacity of these plants is approx. 10 million tons of hot strip per year, representing about a quarter of the total hot strip capacity in India.

JSW ISPAT – A HIGHLY PRODUCTIVE PIONEER

The thin slab pioneer in India was JSW Ispat. The plant, located in Dolvi started production in 1998. In 2003, capacity was doubled by installation of the second CSP® strand.

Designed for an annual capacity of 2.4 million tons, JSW Ispat achieved a monthly hot strip production of 264,300 tons in July 2008. This record value corresponds to 132 percent of the monthly production capacity guaranteed and would result in a yearly production trend of almost 3.2 million tons with two strands and vertical casting machines. JSW Ispat has attained these production quantities through continuously high casting speeds. With a casting speed of 8.0 meters per minute, JSW Ispat holds the world record for thin slab casters.

BHUSHAN POWER & STEEL – IMPRESSIVE SEQUENCE LENGTH AND THIN GAGE PRODUCTION

The CSP® plant of Bhushan Power & Steel in Rengali started production in April 2008 with one casting strand and five mill stands only. The investment costs were also reduced by the relatively small ladle size (90 t) and the short metallurgical length (6,340 millimeter). The strip width of 1,300 millimeters is in line with Bhushan’s cold rolling facility.

After the successful establishment on the market, production was doubled by the second casting strand in 2010. The rolling mill was expanded by a sixth mill stand and a downcoiler, allowing Bhushan to reduce the minimum gage and to optimize its rolling operations. Today, Bhushan Power &
Steel is very much focused on the production of thin strip. In 2010, more than 45 percent of production was ≤ 2.0 millimeters.

Another characteristic of Bhushan Power & Steel is the large number of ladles per sequence. In September 2011, a sequence of 45 heats during a net casting time of 28 hours was cast.

**ESSAR STEEL INDIA – THE WORLD’S FIRST 3-STRAND CSP® PLANT**

The CSP® plant of Essar Steel India will be the first 3-strand CSP® plant worldwide and is designed for a total capacity of 3.5 million tons per year. The plant was supplied by SMS Siemag including the complete electrical and automation system.

Essar Steel India started production at its Hazira based CSP® plant with two casting strands in March 2011. Already during commissioning, the plant showed impressive results. For example, the casting performance was record breaking: three weeks after commissioning, a casting speed of 6.5 meters per minute was realized. In October 2011 Essar Steel achieved a casting speed of 7.0 meters per minute for more than eight hours. The casting process was smooth and characterized by a stable mold level.

Essar Steel India has achieved a remarkable rolling stability and performance for ultra-thin gages. 60 days after the first coil, the first strip with 1.0 millimeter strip thickness was produced and, 135 days after start-up, the first strip with 0.8 millimeter thickness. In August 2011 Essar Steel India realized rolling campaigns of more than 30 strips of ≤ 1.1 millimeter.

**TATA STEEL – INNOVATIVE PRODUCT MIX**

The most recent Indian CSP® plant started operation in March 2012 at Tata Steel’s Jamshedpur facility. The intended product mix of Tata Steel comprises a high share of value-added steel grades such as silicon grades, line pipe grades and dual-phase steels. Tata Steel will use a portion of its hot strip to supply the group’s own automotive factories.

For this plant, SMS Siemag supplied the complete plant and process technology including electrics and automation. Already 45 days after start-up, the minimum strip thickness of 1.2 millimeter was realized. Also, strip quality was excellent during commissioning.
The southern United States has become a new center for the US industry in recent years. It is mainly the automobile industry and its suppliers, who have discovered this region for their business and set up a number of new production facilities there. In contrast, the steel industry today is still concentrated mainly in the traditional heavy-industry regions in the north of the country. This market opportunity was recognized by Severstal Columbus in 2005 (then called Sever-Corr) when it was decided to set up a new facility for the production of high-quality hot and cold rolled steel strip on a greenfield site in the southern state of Mississippi. The production complex of Severstal Columbus includes all stages of production from steelmaking to hot dip galvanizing. All key equipment was supplied by SMS Siemag. This consists of:

- Steel making plant (two electric arc furnaces, two ladle metallurgy furnaces, vacuum tank degassers)
- Two vertical CSP® thin slab casters
- CSP® tunnel furnace
- Tunnel furnace shuttle
- CSP® hot strip mill
- Laminar cooling table with two down coilers
- Push-pull pickling line
- Tandem cold rolling mill
- Two hot dip galvanizing lines
- Batch annealing

From a management perspective, the technology provides a solid base for an effective health and safety program while lending itself to maintaining or exceeding environmental compliance. With turbulent market conditions it is important that production can be easily throttled up or down. With CSP® technology it is easy to manage quality, conversion cost and delivery performance regardless of market conditions or product mix. The equipment and inherent process positions Severstal Columbus well for adapting and capitalizing on growth markets.

OPERATIONAL RESULTS AND RECORD BREAKING PERFORMANCE

Severstal Columbus achieved a very fast start-up in 2007 and ramped up to a high level of production often largely exceeding the design productivity and only interrupted by market downturns. Although designed for casting slabs with nominal width of 1,880 millimeter, the widest slab cast at Severstal Columbus on 10 November 2009 was 1,968 millimeter wide. The hot rolled coil was 1,922 millimeter wide (at ambient temperature).
INNOVATIVE PRODUCT MIX, TAILORED FOR THE AUTOMOTIVE INDUSTRY

One main advantage of Columbus’ geographic location is the vicinity to 19 (of a total of 25) southern automobile factories. These are less than 725 km away from Columbus. In addition, Mexico can be reached via a direct railroad line. Columbus has excellent existing road, rail, water and air traffic connections.

The product mix at Severstal Columbus includes low and medium carbon steel grades as well as microalloyed, Boron and interstitial-free steel grades including grades for the production of car parts. The maximum width of 1,900 millimeter is suitable for automotive parts. In order to fulfill the demands by the customers especially from the automotive industry, Severstal Columbus has implemented a continual improvement process (CIP), rotary scalers at the entry to the tunnel furnace and automatic surface inspection throughout the entire plant.

COOPERATION BETWEEN SEVERSTAL COLUMBUS AND SMS SIEMAG

It was clear from the project phase on that a highly motivated team would operate Severstal Columbus. This lead to the common agreement between Severstal Columbus and SMS Siemag to work together on a number of topics. As a rule, only topics that are interesting to both parties are elaborated within the cooperation and currently the list of topics amounts to a total of 16 topics. The types of projects range from very global topics and the elaboration of operational guidelines (e.g. operation of electro-magnetic brake or improving surface quality) to installation changes such as the bearing block measurement and rotary descaler at the caster, the inline oxidation device at the tunnel furnace, and hot strip speed measurement at the mill.

OUTLOOK

Following the successful commissioning, the fast start-up of production for two electric arc furnaces and two CSP® casters, Severstal Columbus has focused on demanding markets such as automobile factories and high strength pipe material. In the future, Severstal Columbus is looking into possibilities of upgrading the CSP® plant by adding new gears to the hot strip mill, intensive cooling and Liquid Core Reduction in CSP® casters. Further development of automotive grades as well as higher strength line pipe steel and light gage hot strip may be next. All efforts are considered in-line with the stated goal referred to as “Severstal full throttle: 3.4 million short tons”.

1 Overview of Severstal Columbus' plant layout.
2 Automotive industry in the Southern USA.
3 CSP® mill.
SMS GROUP – 50 YEARS OF LEADERSHIP IN CONTINUOUS CASTING

The milestones in continuous casting were set by the SMS group and its predecessor companies (Schloemann, Concast and Mannesmann Demag) and proves 50 years of leadership in continuous casting. The first continuous caster ever was built by Concast AG at Dillinger Hütte, Germany in 1961, followed by the first bending caster in 1964 also at Dillinger Hütte. The first thin slab production caster was commissioned at Nucor Crawfordsville, USA by SMS Schloemann Siemag in 1989 as a VSB (Vertical Solid Bending) type thin slab caster, while the first VLB (Vertical Liquid Bending) thin slab caster was commissioned in 1992 at Arvedi, Italy built by Mannesmann Demag, today SMS Siemag, followed in 2000 by the first VLB thin slab caster with independent vertical and bending segment at Tata Ijmuiden, Netherlands. The records over the last 20 years prove: The SMS Group built “thinner – thicker – wider – faster – more ….” than anybody else. On-going record-breaking production and performance figures proves the CSP® casting technology as the most flexible and reliable technology on the market. Today, customers receive the complete mechanical and electrical equipment as well as the automation system from a single source, which leads to steep start-up curves. For example, Severstal Columbus had reached 90 percent of its rated capacity after just five months. The annual production record was more than 1.5 million t/year on one strand with a containment length of just 8 meters. A monthly record was reached with 138,195 tons, which would correspond to an extraordinary annual production of 1.65 million t/year.

EXTENDED CSP® CASTER PORTFOLIO

New market demands require an even higher production and/or an increased final strip thickness for special applications (like thick API grades). The casting thickness therefore needs to be increased and the extended metallurgical length of the caster consequently leads to a VLB type caster. The new CSP® VLB casters are based on SMS Siemag’s more than 20 years of experience in thin slab casting and combines proven CSP® technology with new technical solutions. The design capacity depends on the metallurgical length and will reach 2.0 million t/year (at 1,350 millimeter average width). Additionally, this caster fulfills the requirements for endless rolling.

The extended CSP® caster portfolio still covers the VSB type casters with the unique, wholly vertical strand guide system and production volumes of up to approx. 1.6 million t/year per strand. Both caster types complement each other and offer optimal conditions for the different requirements. Common to both types is the identical machine head as the core component for reliable casting of thin slabs.

CSP® CASTING TECHNOLOGY – MACHINE HEAD

The heart of the CSP® caster is the original CSP® funnel-shaped mold with parallel exit at the end of the mold and with its integrated narrow side adjustment. The most reliable Mold Monitoring System (MMS plus) includes the detection of longitudinal cracks to allow an even more immediate response of unfavorable casting conditions, while the electromagnetic brake (EMBR) with the window design improves...
Extended CSP® caster portfolio to meet new market demands.

CSP® VLB ultra high production caster.

Historical milestones in continuous casting driven by the SMS group.

- First VSB slab caster (Dillinger Hütte, Germany)
- First bow type slab caster (Dillinger Hütte, Germany)
- First VSB thin slab production caster (Nucor Crawfordsville, USA)
- First VLB thin slab production caster (Arvedi, Italy)
- First VLB thin slab caster with independent vertical and bending segment (Tata Ijmuiden, Netherlands)

The quality due to reduction of mold powder entrapments and surface cracks at high throughput. All these components have been successfully used for many years and undergone permanent further development warrant reliable casting operations. The adapted leaf spring guided “resonance oscillation” unit whose reliability and extremely high running accuracy (“zero-displacement”) has been known from conventional continuous casters, features a very compact design and is the new standard for all types of CSP® casters.

The vertical segment 1 is easy to maintain and identical in all CSP® casters. As 95 percent of all breakouts remain in segment 1, the simple maintenance of this segment is a decisive factor. Mold and segment 1 are designed as a quick-change unit, which in many cases makes the caster ready for casting again within less than one hour after an incident. Segment 2 of the VLB type caster is an independent bending segment, which has the same roller apron as the VSB type caster.

CSP® CASTING TECHNOLOGY – STRAND GUIDE UNIT

Particular attention is paid to the strand guide unit with its minimized and uneven roller pitch for even better quality due to reduced bulging and strain. Following the axle rollers in segment 1 and 2, patented STEC rollers are used in the further course of curved and horizontal strand guiding. For the first time, this novel roller allows the combination of internal roller cooling with narrow bearing windows and small roller diameters. The design is also used for driven rollers. Furthermore, the special design of the STEC rollers allows quick dismantling and subsequently an easy maintenance. Thickness reduction is effected in segment 1 or in segments 1 and 2 (LCR plus – Liquid Core Reduction) using the position-controlled cylinders of the hydraulic segment adjustment system HSA. In 2010 a record breaking thickness reduction of 35 millimeter for LCR grades was achieved at Maanshan Iron & Steel in China for the first time. Samples show the very small amount of bulging of the narrow sides and the homogeneous internal structure. The extended variety of casting thickness without the need for changing over the caster increases the flexibility of producing material both with thick and very thin final dimensions. The Dynamic Taper Setting (DTS) with its minimal force control in the downstream segments ensures, irrespective of the casting speed or the shrinkage behavior of the strand, an optimal strand support at all times. Further, a maximum force monitoring ensures active segment protection (ASP – Active Segment Protection).

The CSP® VLB type caster also comes with proven features of conventional caster technology such as CYBERLINK segments, air-mist cooling, tunnel type cooling chamber and top feeding dummy bar system.

SUMMARY
The CSP® casting technology is the most applied thin slab technology in the world and ensures absolute reliable casting process and highest flexibility to meet the individual customers’ production requirements.
The near-net-shape horizontal belt casting of steel opens up new technological possibilities. Many of the steel grades which presently entail yield losses in conventional plants are expected to be profitably produced in BCT® (Belt Casting Technology) installations. For the first time, steels with extraordinary properties can now be produced on an industrial scale. A current example is HSD® (high strength and ductility) steel with its high contents of manganese, silicon and aluminum which is lightweight, high-strength and at the same time easily deformable. All this is made possible by casting metal into the moving mold without the addition of casting flux, as well as stress-free horizontal solidification of the as-cast strip.

The rapid solidification in an inert atmosphere opens up a wide range of potential charge materials. The caster may be combined both with BOF and EAF melt shops. BCT® installations are specifically tailored to the needs of customers. Medium-wide strip can be produced just as well as hot wide strip. Customers with small production capacities will be served by the appropriate installation, as will steel producers with medium-to-high annual tonnages.

Compact BCT® casting-rolling installations will produce 15 millimeter thick as-cast strip – a near-net-shape thickness that allows both a sufficient deformation degree to attain optimal mechanical properties and saves deformation energy, space and eventually cost.

BCT®: WORLD’S FIRST INDUSTRIAL PLANT
In May 2010, Salzgitter Flachstahl awarded SMS Siemag a contract for the supply of the world’s first horizontal, industrial-scale BCT® caster. SMS Siemag’s wealth of experience in the planning, construction and trial operation of the pilot plants set up at the MEFOS Research Institute in Sweden as well as at the technological competence of Technical University of Clausthal were essential factors that contributed to the development and design of the new machine.

The new BCT® caster was installed at Peiner Träger GmbH (Salzgitter Group) steelworks. The caster will produce 15 millimeter thick and 1,000 millimeter wide material. Essential parts of the plant are already rated for a width of 1,600 millimeter to allow the future extension of the product line. At the end of 2012, the new BCT® facility will be jointly commissioned by the cooperation partners Salzgitter Flachstahl and SMS Siemag.

BCT®: PROCESS AND MAIN CHARACTERISTICS
Protected from reoxidation, the liquid steel is poured via a submerged entry nozzle into the preheated feeding system. From this system the steel flows onto the moving horizontal mold which consists of the conveyor belt and the internally cooled side dams. The underside of the conveyor belt is intensively cooled by water and operated at speeds of up to 30 meter per minute. No oscillating mold is therefore needed for initial solidification and no addition of casting flux is required.
Above the conveyor belt an inert gas atmosphere protects the solidifying steel. A defined gas mixture directly influences the solidification structure. Electro-magnetic units to influence the steel flow as well as cooled hoods are arranged above the conveyor belt. A transverse stirrer supports the smooth and uniform distribution of the liquid steel up to the side dams. A longitudinal stirrer synchronizes the movement of the conveyor belt with the liquid steel flow. The as-cast strip leaves the conveyor belt horizontally. It is guided by a top roller and three pairs of ironing rollers that can influence the flatness of the strip. The as-cast strip then enters an enclosed roller table in which the complete inertization of the process is ensured up to the end of the table.

The roller table is followed by a combination of two pinch-roll stands and a looper arranged in between. In addition to the further transport of the as-cast strip, it decouples the BCT® caster and the downstream units. The second pinch roll unit feeds the strip to a moving hydraulic shear. For cutting the strip to the desired sheet length, the shear is accelerated to the as-cast strip speed.

The main characteristics of BCT® are:
- Horizontal casting process
- Moving mold, no oscillation
- Free of casting powder
- Stress-free solidification
- Protection from reoxidation by inert gas atmosphere
- Indirect cooling
- As-cast strip thickness with a sufficient deformation degree

**CONCLUSION**

The newly developed plant concept based on Belt Casting Technology is now realized by SMS Siemag AG for the first time on an industrial scale. In a cooperation project with Salzgitter Flachstahl GmbH this plant is used to implement the near-net-shape casting of HSD® steel grades. During the first stage of the project, the BCT® caster will produce 15 millimeter thick and 1,000 millimeter wide as-cast strip. The plant was set up at the steelworks of Peiner Träger GmbH, a company of the Salzgitter Group and will start operation by the end of 2012.

The Belt Casting Technology makes it possible to produce new steel alloys, with horizontal strip casting offering an opportunity for the production of steel grades which in conventional installations can be cast to a limited extent only. BCT® is characterized by stress-free solidification, with no casting flux required for this process.

BCT® installations are flexible when it comes to their integration in new or existing BOF or EAF melt shops. The production capacity and product dimensions are designed specifically for each customer.
MAINTENANCE SERVICES FOR PLANT LIFE TIME EXTENSION

Today, maintenance service is no longer thought of as a mere cost factor. It becomes more and more a continuous factor for the efficient operation of advanced high-capacity installations. SMS Siemag and its worldwide service locations function as reliable and local partner to all customers. Based on over 100 years of experience, SMS Siemag service offers solutions to all challenges during the complete life-cycle also of CSP® plants for an optimal operation at any time.

Maintenance is increasingly thought of as an integrated factor for efficient operation of advanced high-capacity installations in the metallurgical industry and no longer as a mere cost factor which is to be maintained as low as possible. An intelligent mix of the various maintenance and repair strategies may lead to a significantly higher availability along with optimized costs at the same time. “Break-and-fix” maintenance strategies only at first glance seem to result in savings. It makes more sense to implement a continuous improvement process in a plant in addition to the optimum maintenance mix. This makes the plant perfectly fit for the changing requirements of the market.

Given their complexity in plant and process technology, CSP® plants offer a great number of starting points for services of SMS Siemag with a view to increasing the plant’s availability and efficiency significantly. The SMS Siemag service portfolio for CSP® plants comprises ladle turret inspections, mold services, the inspection and repair of HGC cylinders and CSP® blocks, spindle and Morgoil® services and mandrel repairs to name but a few examples. SMS Siemag also offers Condition Monitoring, a 24/7 remote service and different consulting services like fact findings or maintenance audits.

**SIEFLEX® DRIVE SPINDLE SERVICE**

An upgrade of existing drive spindles by the optimized Sieflex® spindle with continuous oil circulation lubrication of the „tube solution“ design concept allows higher maximum load transfer rates, greater possible transmission angles and a longer gear teeth lifetime as compared to conventional universal joint shafts. With the installation of these spindles in the finishing mill drive train section, the more stringent requirements of the market in terms of higher strengths can be satisfied.

The design concept of the Sieflex® spindle is so flexible that it can serve as a replacement for other drive spindle systems without difficulty. They are overhauled in the SMS Siemag service workshop in Suzhou and they are restored to a “as-good-as-new” condition. Existing Sieflex® spindles may also be revamped to the tube solution design in this workshop and this revamp is of a quality which one may expect from the OEM (Original Equipment Manufacturer).

Furthermore, the service workshop in Suzhou is able to repair other parts such as adjusting cylinders, CVC® blocks and even coiler mandrels in world class quality.

**MORGOIL® SERVICES**

On the basis of almost 60 years of experience and a long term relationship with notable steelmakers worldwide, SMS Siemag offers the full range of oil film bearing products and related services. SMS Siemag is constantly further developing...
the bearing technology and advises its customers in the planning of new bearings but also in upgrades and repairs. In the new workshop in Suzhou, SMS Siemag invested into new equipment for machining and assembly of Morgoil® bearings in China. SMS Siemag will be focused on its customers’ demands and will provide tailored solutions, like the symmetrical bearing concept with stronger and shorter backup roll necks resulting in increased work safety and a significant reduction of maintenance cost. The new sealing systems for hot and cold rolling mills considerably contribute to environmental protection and significantly provide to economic operation of hot strip mills.

The portfolio of Morgoil® services includes:
- Short-term delivery due to local manufacturing
- Manufacturing of new Morgoil® bearings including machining and assembly
- Repair services
- Full range of OEM spare parts for all Morgoil® bearings
- Technical support and on-site service
- Bearing modernizations and upgrades.

GENIUS CM CONDITION MONITORING SYSTEM
Components of CSP® plants are partly subjected to extreme loads. Especially the failure of these parts like the drive train of the CSP® mill would result in the loss of the complete production. To prevent this, the use of online monitoring systems is required. The mere display of measured values such as temperatures, vibrations and torques like in traditional condition monitoring systems does not provide the desired monitoring result. An evaluation of the measured data along the current production data of the plant is required to draw conclusions about the actual condition of the monitored components. Only the design engineer of the plant is able to do this evaluation. No one else knows the design parameters of the components and the components’ load limits.

The Genius CM condition monitoring system of SMS Siemag is capable to perform this monitoring and analysis. It allows the monitoring of actual loads for the determination of equipment condition and furnishes relevant information before an unscheduled plant standstill strongly reduces the availability.

Genius CM features modules for all critical elements of a CSP® plant like the drive system, oscillation, vibration chatter, hydraulics or shears. It is of a modular structure which allows simply extending it as required. In addition, its operation is web-based which is why it can be started independently from the various operator stations in the complete network.

SMS Siemag has developed a wide-ranging portfolio to optimize life-cycle costs. The aim of this has always been to be a life-cycle partner for our customers and to assist them in all day-to-day issues and challenges.
MOld refUrbISHMeNt ServICeS

SMS Millcraft started mold refurbishment business already in 1968. One application is Mold Refurbishment/Repair Service, which has a 70 percent market share of the mold copper refurbishment business in the USA. This technology is supported by the worldwide SMS Siemag service network experts and is by now fully introduced in China. In recent years it was also established in India, Turkey and Brasil. One important application is the coating of copper molds in continuous casters. Our maintenance division in the USA has been providing maintenance services to CSP® and other high-speed caster designs in North America since the early 1990ies.

COAtING Of CSP® MOld COPPerS
The advantages of coated mold coppers are:
- Extension of copper life – protection against wear
- Increase of caster efficiency – extension of campaign lengths
- Improvement of product quality – prevention of “star” cracks and decrease of potential of longitudinal face cracks
- Maintaining proper dimensions at mold exit and funnel “lip”

Due to the nickel plating, the mold campaign lives are 2 to 3 times longer compared to uncoated mold copper. Nickel or Nickel-Cobalt step configurations are cost effective at stopping mold wear and star crack defects on the slabs. Due to the high casting speeds and the resulting high heat flux, typically only step nickel plating configurations are used for CSP® molds. For CSP® BFS coppers that do not have serious meniscus cracking issues, a thick nickel step (approximately 2 millimeter thick) can allow for the hot face to be machined after a period of use. The coppers can then be reused without replating. Due to the SMS Siemag Mold Coating Technology, campaign and overall copper lifetimes can be extended 2 to 3 times.

THERMOCOUPLE MAINTENANCE AND WATER JACKET REFURBISHMENT
The MMS (Mold Monitoring System) utilized with CSP® molds are an important asset to a proper operating casting machine in order to reduce and prevent breakouts as well as to provide a thermal map showing heat removal variances. Maintenance and testing of the spring loaded thermocouple system can be performed within the SMS Siemag mold maintenance workshop to keep the MMS working as it should. For those CSP® casters who have carbon steel water jackets, scale and corrosion build up inside the broadface water jackets can be an operational issue. Water flow blockages caused by loose scale in broadface water jackets and coppers can cause non-uniform heat extraction resulting in longitudinal face cracks or “caster folds”. In order to prevent scale formation inside carbon steel water jackets, the internals of the water jackets can be grit blasted to remove loose scale and then be powder coated.

FOR LONGER COMPONENT LIFE TIME, INCREASED PRODUCTION AND IMPROVED QUALITY, COATING TECHNOLOGIES HAVE GAINED IMPORTANCE IN THE PAST DECADES. SMS SIEMAG AND THEIR SUBSIDIARIES HAVE ALWAYS PLAYED A KEY ROLE IN THE DEVELOPMENT OF NEW TECHNOLOGIES AND APPLICATIONS. TODAY COATING TECHNOLOGIES CAN BE USED THROUGHOUT THE PRODUCTION CHAIN TO SIGNIFICANTLY IMPROVE THE EQUIPMENT PERFORMANCE.
CURRENT REFURBISHMENT WORK IN CHINA SCW WORKSHOP

The refurbishment starts with a detailed analysis of the casting machine and its needs so that a customized coating configuration can be determined. Due to the box coating process, the coppers can stay on the water boxes throughout the refurbishment process improving final deposit thickness uniformity while reducing turnaround time and costs. Below is a brief outline of the process steps followed when refurbishing a set of CSP® broadface coppers:

- Steam clean mold
- Re-torque copper mounting bolts and water test
- Machine to remove used coating and meniscus erosion/cracking
- Nickel plate mold coppers
- Final machine mold coppers
- Final water test
- Perform nickel quality test
- Grind hot face
- Paint water jacket
- Final inspection
- Prepare for shipment

Assembled molds provided with both the copper and water jacket receive an incoming water test and in case of leakage, any issue must be resolved before continuing on. This could involve complete or partial disassembly and replacing sealing devices or by welding and remachining the copper mounting surface. Water jacket flatness is important and should be checked when normal copper replacements are done or when a mold has experienced a high-temperature event that may have resulted in distortion to the water jackets. The copper plates (assembled status on water jacket) were machine checked on Zimmerman 5-axis milling machine. In case the customer’s funnel area profile is different from drawing, the coppers will be finish machined according to the drawing.

After Nickel plating the broadface copper is finish machined (plating and final machining is done with the coppers assembled to the water jackets), nickel layer is tested for adhesion.

CONCLUSION

With the modern machining set up, process know-how and abroad trained employees in the new maintenance facility in China, SMS Siemag can offer full mold maintenance services. Combined support from SMS Siemag in Germany as the OEM and the maintenance know-how from SMS Millcraft (USA) have strongly positioned SMS Siemag to be a market leader in China. Besides basic mold refurbishment services such as machining and coating the facility can also repair water jackets and perform thermocouple maintenance. Services to improve or upgrade mold and copper designs and implement new technology are also available.

After many years of successful establishment, the service division of SMS Siemag in China can handle all challenges. Nevertheless, SMS Siemag will not rest and will continue to extend its service products, in order to support customers in China to face everyday challenges.
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