X-CAST® TECHNOLOGY ENSURES A WIDE PRODUCT RANGE[1]

Continuous casting solutions by SMS Demag

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Abstract
SMS Demag AG is the SMS group's Metallurgical Plant and Rolling Mill Technology Business Area and can look back on a 200-year-old tradition. SMS Demag has pioneered continuous casting by the development of key innovations such as the hydraulic mold oscillator or the Dynamic Soft Reduction process. Today, continuous casting machines supplied by SMS Demag come with X-Cast technologies. These casting machines combine high productivity through short set-up times, permanent availability, ensure excellent surfaces and a high internal slab quality with a homogenous microstructure. The great success of our X-Cast technology basically has been pushed by the Intelligent Slab Casting ISC® concept, which comprises dedicated technologies that are constantly improved. The heart of ISC® is the CYBERLINK® technology. ISC® enables plant operators to utilize their machines to produce new and demanding steel grades of a constantly high quality at a wide range of thicknesses and widths. Detection of point of solidification by using the Dynamic Solidification Calculation or by using online measurement with CyberTracking, Dynamic Soft Reduction and Dynamic Drive Control are only a few outstanding technologies from SMS Demag. The Dynamic Drive Control serves for a safe withdrawal and significantly reduces sticking strands. Together with the modern Secondary Spray Water System including its width dependent cooling technology our customers are provided with the leading plant technologies. Hence, using SMS Demag's casting technologies is giving the essential advantage in production of pipe and plate grades.
Key words: Continuous casting; Dynamic soft reduction; Process control; Solidification.

A TECNOLOGIA X-CAST® GARANTE UMA AMPLA GAMA DE PRODUTOS SOLUÇÕES PARA LINGOTAMENTO CONTÍNUO DA SMS DEMAG

Resumo
A SMS Demag AG é a divisão do grupo SMS dedicada a plantas metalúrgicas e tecnologia de laminação, com uma tradição de 200 anos. A SMS Demag foi pioneira no lingotamento contínuo com o desenvolvimento de inovações fundamentais, tal como o oscilador hidráulico para moldes ou o processo de redução dinâmica suave. Hoje, as máquinas de lingotamento contínuo fornecidas pela SMS Demag são equipadas com a tecnologia X-Cast. Estas máquinas de lingotamento combinam alta produtividade através de curto tempo de ajuste, disponibilidade permanente, garantia de excelentes superfícies e uma alta qualidade interna da placa com uma microestrutura homogênea. O grande sucesso de nossa tecnologia X-Cast tem sido basicamente impulsionado pelo conceito do lingotamento inteligente de placa ISC®, que compreende tecnologias dedicadas que são constantemente aperfeiçoadas. O coração do ISC® é a tecnologia CYBERLINK®. O ISC® permite aos operadores da planta utilizar as suas máquinas para produzir novos tipos de aço que exigem alta qualidade constante, com uma ampla variedade de espessuras e larguras. A detecção do ponto de solidificação utilizando o Cálculo Dinâmico de Solidificação ou medições online através do CyberTracking, da Redução Dinâmica Suave e Controle Dinâmico do Acionamento, são apenas algumas das tecnologias de destaque da SMS Demag. O Controle Dinâmico do Acionamento serve para uma retirada segura e reduz significantemente a aderência de lingotes. Juntamente com o moderno Sistema Secundário de Borrifação de Água, incluindo a sua tecnologia de refrigeração em função da largura, fornecemos aos nossos clientes as tecnologias de ponta para usinas. Por isso, utilizar as tecnologias de lingotamento da SMS Demag significa ter uma vantagem essencial na produção de tubos e chapas de qualidade.
Palavras-chave: Lingotamento contínuo; Redução dinâmica suave; Controle de processo; Solidificação

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1 INTRODUCTION

For us, the market requirements are a daily yardstick. The challenge we face is to design plants that can satisfy the needs of the market long after the commissioning of the caster or at least can be adapted to future requirements.
The market nowadays demands more and more for high sophisticated steel grades for the automotive and construction industries, for bridges, power plants and for tube and pipe production. Pipe grades namely up to API X-100 are of special interest and under developing. Only a very few steel making companies are able to produce these steel grades fulfilling the strong requirements. SMS Demag's continuous casting machines come with X-Cast technologies that ensure these requirements like excellent surfaces and a high internal slab quality with a homogenous microstructure. X-Cast is a brand name introduced by SMS Demag in 2007 which combines selected technologies (please refer to following chapters). At the same time these casting machines combine high productivity through short set-up times and permanent availability.

2 SOLUTIONS BY SMS DEMAG

2.1 Machine Design

At the beginning of the engineering phase first the design of the machine (mold, strand guide, segments, cooling, etc.) is of highest priority. Especially the segments are of great interest. Our segments feature particular suited stiffness of frames, rolls and bearings resulting in uniform distribution of applied force. The heat transfer into the roll bearings could be minimized and therefore the life time could be fundamentally increased.
One proven development is our CyberLink segment with its top frame connected only by two levers feature self alignment and results in less roll wear and maintenance costs.

2.2 Steel under Pressure – Dynamic Soft Reduction

Especially for heavy plate grades undergoing just a small amount of final deformation, the design of the slab's core zone plays an important role in the downstream rolling process. A clear improvement of core quality is attained by Dynamic Soft Reduction by means of both solidification fronts being compressed through hydraulic adjustment of the segments in the final solidification zone.[(1)]
This operation can be controlled by presetting the position of the point of solidification, i.e., with the help of the DSC (Dynamic Solidification Control). Dynamic Soft Reduction is usual performed in the segments of the horizontal part. The first caster having the Dynamic Soft Reduction process applied in the curved part (segments 4 and 5) of the machine is the one at Anyang Iron & Steel.
To accomplish Dynamic Soft Reduction process, the segment top frame is set in the calculated area of the point of solidification to a more defined wedge shape in line with the requirements for the respective steel grade to reduce the slab's core porosity and macro segregation.
Especially for heavy plates susceptible to segregation, this is a major improvement in the internal quality of the slabs.

2.3 Latest Development – Remarkable Advantage

The interaction between steel grade, casting speed, secondary cooling and strand guiding demands variable parameters for the length and rate of the Dynamic Soft Reduction process. Evaluation of all dependencies to be taken into account and setting of Dynamic Soft Reduction parameters is done by our DSC. Beneath the determination of the point of solidification using the DSC another method which takes advantage of the changing mechanical and dynamical behavior of the strand as a function of its location has been proven at Salzgitter Flachstahl GmbH. For this the top frame of the CyberLink segment (Figure 1) oscillates with an amplitude of up to some 1/10 of a mm. Using the phase difference of the cylinder force and position, the area of hysteresis of one oscillation movement can be calculated. This value indicates the position of the point of solidification. Two modes are available, i.e., a steady and an unsteady mode. Using the steady mode, the top frames of all the CyberLink segments are oscillated for a short time after another under steady-state casting conditions. Using the unsteady mode, the top frame of only one CyberLink segment is oscillated for a longer period, especially during transient operation such as casting speed changes. Operating practice has shown that top-frame oscillation using small amplitudes does not negatively affect the inner quality of the slab.

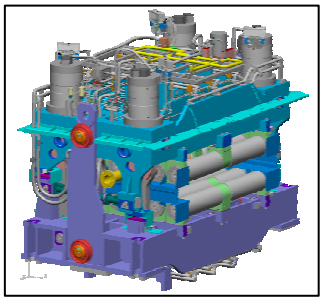

Figure 1. CyberLink segment

In parallel the SMS Demag Dynamic Drive Control that has been especially designed for the CyberLink technology serving for optimal distribution of the total torque needed to safely withdraw the strand to each individual driven roll.
In doing so, the actually measured force of the hydraulic cylinders of the CyberLink segments, which may vary among the segments for different process conditions (e.g. using Dynamic Soft Reduction), is taken into account for each segment.
To increase the lifetime of the segments (rolls, bearings), we integrate a segment overload protection concept in the hydraulic and automation systems.
The Dynamic Solidification Control (DSC), the feedback of the actual strand forces (in different process situations) and the Dynamic Drive Control are integrated in the ISC® (Intelligent Slab Casting). ISC® serves for a maximized yield. Increasing of casting speed results in a maximum positioning of the final solidification in the last segment. So the complete machine length can be used and at the same time bulging of the strand behind the strand guide system is avoided.

3 TAILORED SOLUTIONS – SPECIAL TYPE OF DESIGN

3.1 Maanshan Iron & Steel Co. Ltd. – High Productivity

3.1.1 Plant characteristics

The both casters at Maanshan Iron & Steel Co. Ltd. (Masteel), People's Republic of China, are designed for a joint production of 5.7 million tons of flat products each year. With a casting speed of up to 2.2 m/min, they cast slabs of widths between 950 and 2,150 mm and thicknesses of 230 and 250 mm.
Both caster consisting of two strands and they are of identical design only differing in respect of their machine length in the horizontal section. Two strands work with 15 where the other two strands work with 19 segments. The maximum length therefore is 42.6 m (19 segments). On the casters, Masteel produces sophisticated grades for the automotive and construction industries, for bridge-building, power station plant and for tube and pipe production (e.g. X80).

Figure 2. Strand guide system

3.1.2 Tailored machine concept

Another customer of SMS Demag producing high demanding steel grades is equipped with the leading X-Cast plant technologies. Flexible strand guide elongation is prepared to increase production later on to react on market requirements dynamically. One of the two strand caster is equipped with less segments than the other one, but is considered due to the modular design of the X-Cast components for extension.

3.1.3 Air-mist secondary cooling system

The whole strand guide system is divided into a maximum of 20 spray zones. The spray zones on the top of the caster are equipped with 3 control loops and the lower spray zones (from spray zone 3 to the end of the strand guide) are equipped with 2 control loops spread along the casting width, our so-called control-concept, which decreases the flow rates down to a defined minimum rate for small slab sizes (to avoid overcooling of slab edges).
Spray zones 1 to 3 are equipped with water nozzles, whereas all other spray zones are designed for air-mist cooling.

3.1.4 Strand guide

All four casting strands are designed for a maximum of 19 segments. The segments 10 to 19 (15) are of CyberLink design where the segments 3 to 9 are hydraulically adjustable segments. So Masteel is well prepared to be able to place Dynamic Soft Reduction process beginning from the area of the casting bow up to

the end of the strand guide system if necessary. Because of the horizontal segments in CyberLink design Masteel is reducing its maintenance costs (reduced roll wear) and benefits from the Dynamic Soft Reduction.

3.2. Anyang Iron and Steel Company - The World's Widest Slabs (2)

3.2.1 Plant characteristics

The caster produces medium slabs which are up to 3,250 mm wide and 150 mm thick. Optionally, the caster can be revamped to a slab thickness of 130 mm. At a machine length of 18.6 meters, the length of the vertical section is 2.5 m. The maximum casting speed is 2 m/min (which corresponds to seven tons of steel per minute at maximum width and speed). The new facility will be used to produce high-grade slabs for the manufacture of hot strip and heavy steel plates.
The new installation will boost Anyang Iron & Steel Company's production capacity by 1.1 million tons of steel slabs per year to a total of 6 million tons.

Figure 3. Anyang Iron & Steel

The continuous caster, which is designed as vertical-bend unit, will be used to cast high-grade steels. The metallurgical range extends from high-strength, micro alloyed structural steels to sophisticated pipe grades and steel for boiler plate, ship building and bridge plate. With the plant layout matched to the slab width, a high internal quality of the slabs is ensured at high casting speeds.
With 90% of the planned steel grades hot-charged, the requirement for the cost-effective production of high-grade hot strip and heavy plates is satisfied.

3.2.2 Tailored machine concept

Essential components were rated and designed by SMS Demag's engineers specifically for the wide slab size. The wide sizes require a uniform dissipation of heat over the entire contact surface of the mold and strand, to ensure homogenous fusion of the casting flux and hence a uniform heat dissipation and lubrication effect between the strand shell and mold surface.
Owing to the high thickness-to-width ratio (150 mm to 3,250 mm, ratio 1:22), special solutions were developed like described in here.

3.2.3 One submerged entry nozzle for every width

For the world's widest mold SMS Demag has developed a new submerged entry nozzle geometry (Figure 4).

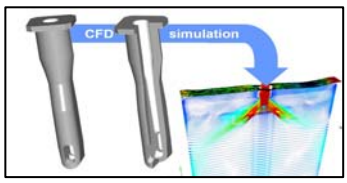

Figure 4 Flow simulation

To be able to use the same submerged entry nozzle for all sizes and casting speeds, the nozzle was developed and optimized by complex flow simulations (computational fluid dynamics CFD). This new development warrants a homogenous flow pattern within the mold under all production conditions.
In the flow analysis conducted, a surface flow at the mold level of less than 0.38 m/sec at a maximum casting capacity of 7.5 t/min was able to be achieved. Even at the lowest casting capacity of 1.75 t/min, excellent values for the surface flow of 0.17 m/sec were established at the mold level. The predicted results were very close to the figures which could be reproduced in operation later on. This confirms the high accuracy and validity of the simulation.
In practice, a sequence comprising 16 ladles per sequence cast through one submerged entry nozzle has already been attained.

3.2.4 Mold

For the geometry and design of the strand surface a compact-type mold was selected (Figure 5). A 1.0 mm thick nickel alloy was galvanically applied to the copper mold. The mold has three rows of thermocouple elements extending over its circumference which serve as measured-value transducers of the Mold Monitoring System MMS.

Figure 5. Compact mold

The mold cooling water flowrate of the primary cooling system is controlled and monitored in the operator control station. With this, the cooling-water flowrate is set specifically to the wear on the mold, to the casting-powder properties and to the steel grade.

3.2.5 Strand guiding segments

After the strand exits from the mold, its precise guiding is of paramount importance. A closely spaced roller frame which is carefully aligned to the mold and consists of nine segments (segment 0 plus eight segments) warrants the uniform contact of the strand with the wide faces in the lower mold area.
The strand is driven on both sides by the upper and lower center roller, thereby ensuring exact guiding of all slab sizes. To apply uniformly the necessary torque along the cast width, both sides (left and right) of the center rollers are equipped with synchronized strand drives.

Figure 6. Horizontal segment

From segment 2 onwards, each segment has seven rollers fitted with a hydraulic position and force control system. To protect the segments against excessive mechanical loads, primary position control is overridden by force control as soon as the parameterized limit forces are exceeded (segment safeguarding). Thanks to the hydraulically adjusted segments, casting may be started immediately after changing to a different slab thickness. Due to the technically consistent implementation of all electro-hydraulic control systems and the mechanical design features of the caster, it is possible to comply with the extremely close tolerance requirements in terms of the slab geometry.

3.3 Tokyo Steel – Special Cooling

3.3.1 Plant characteristics

The new two-strand slab caster for Tokyo Steel in the Japanese town of Tahara is designed for an annual production of 2.4 million t of steel slabs. It is a vertical bending plant, constructed with 16 segments for a metallurgical length of 35 metres, and it will attain a maximum casting speed of 2.2 m/min. Tokyo Steel is Japan's largest producer of electric steel and with its new facility Tokyo Steel will manufacture ULC and IF grades as well as low and medium carbon grades.

3.3.2 Technology package

Both strands will be equipped with the Intelligent Slab Casting package containing technologies which have an essential influence on quality, such as Dynamic Soft Reduction and Dynamic Solidification Control (DSC) with air-mist secondary cooling.
Modern concepts for continuous casting machines with high throughputs place high demands on the spray nozzle system in the strand guide system. This is achieved by using Dynamic Solidification Control DSC which controls the amount of water sprayed onto the strand. The whole strand guide system will be divided into 18 spray zones. The top spray zones (up to spray zone 12; segment 8) will be equipped with control loops spread along the casting width using air-mist nozzles (our so-called control-concept see Figure 7, that decreases the flow rates down to a defined minimum rate for small slab sizes).

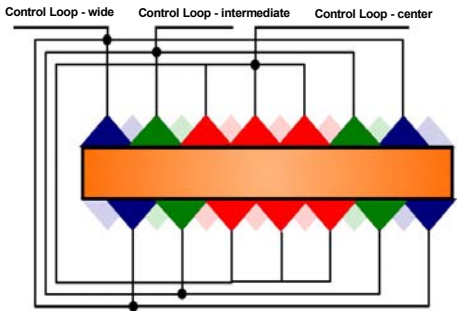

Figure 7. Width-dependent control system Cooling

Segments 9 to 16 (spray zones 13 and 14) will be equipped with flat jet water nozzles. The technological Spot Cooling will be realized with additional control loops before slab straightening.
Further main technology items are:

1. SEN Quick Change Device
2. Resonance Mold
3. Mold Monitoring System
4. Mold Width and Taper Control
5. Segment Gap Control

4 CONCLUSION

A lot of different requirements like production mix, final use of products, especially strong requests to material properties, as well as casting speed in conjunction with machine length and section range is taken as a basis for the design of the machine. So the caster concept differs from customer to customer according his requirements. Only an optimal solution for the specific requirements can fulfill the specific needs of the different plants.
Hence the interplay of the before mentioned and the X-Cast technologies like Dynamic Soft Reduction, optimal secondary cooling or Dynamic Drive Control is of great importance since ever before.
SMS Demag has proven world's leading technologies for the production of the world's widest slab caster (Anyang Iron and Steel Company) as well as high productivity caster like Maanshan Iron & Steel Co. Ltd. with 42 m length. The new caster at Tokyo Steel with the design solution for Spot Cooling device will be a further demonstration of innovative plant design from SMS Demag.

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