6-strand bloom caster,
Pangang Group Steel Vanadium
& Titanium Co., Ltd., China

FEATURING 16

CONTINUOUS CASTING

papers from Primetals Technologies at the ECCC Conference 2017 in Vienna covering the topics of slab casting, billet casting, bloom casting, strip casting, and the related mechatronic, automation and process-optimization systems.

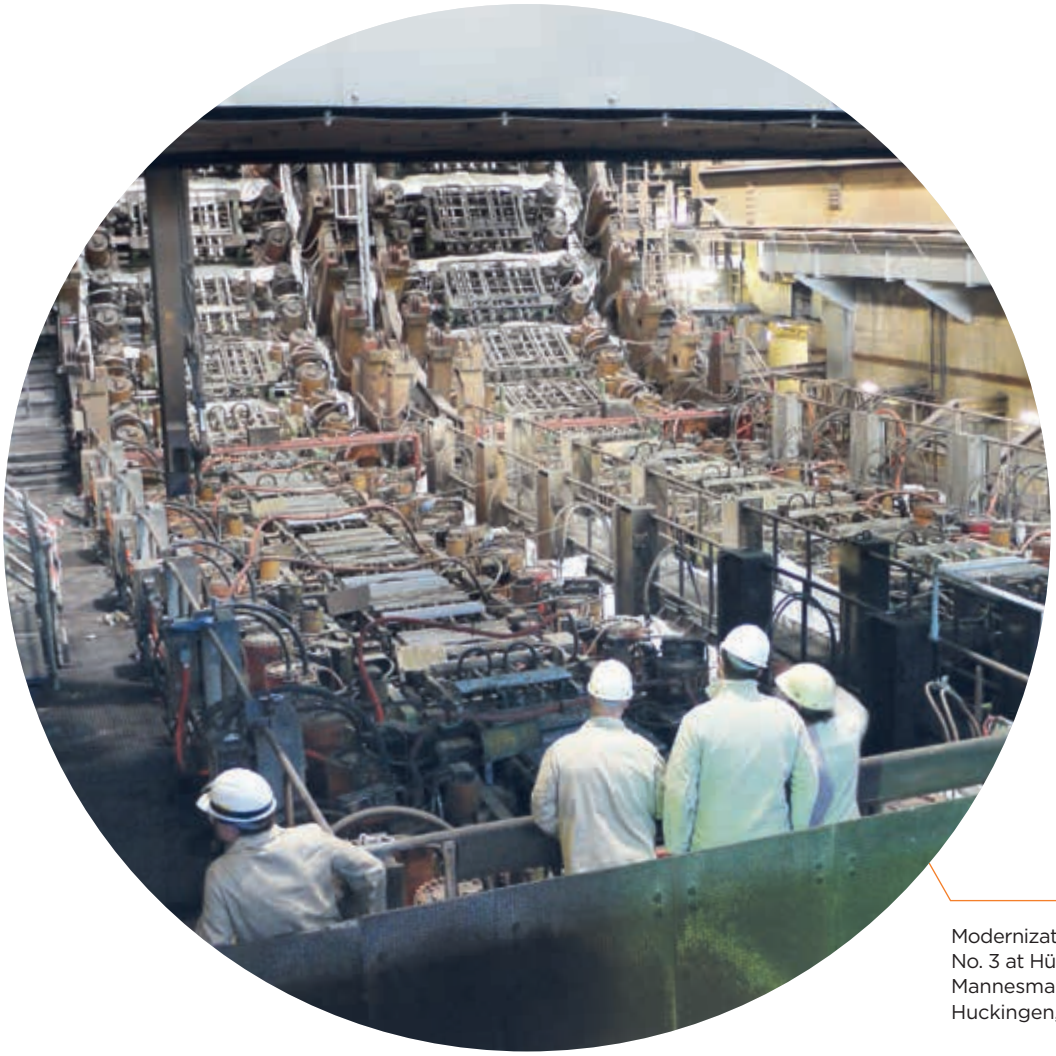
HKM OPERATION RESULTS: EFFECTIVE USE OF PRIMETALS TECHNOLOGIES PROCESS MODELS

Paper number: 22; Principal author: Martin Hadler

In May 2015, the modernized Slab Caster No. 3 at the Hüttenwerke Krupp Mannesmann GmbH (HKM) Duisburg-Huckingen plant in Germany went into operation. The revamp was carried out by Primetals Technologies with the following main targets: improvement of the quality and product tolerances of the cast slabs; extension of the product portfolio; and increased process stability, availability and workplace safety.

To achieve these goals, the latest technological packages from Primetals Technologies were installed. Basic and process automation as well as safety equipment were completely overhauled. Sophisticated caster solutions and process models such as DynaPhase, DynaGap Soft Reduction, Dynacs 3D, LevCon, DynaWidth and DynaFlex were implemented. In combination with the air-mist secondary-cooling system, which also had been renewed, a new surface-temperature control system was applied to ensure the continuous production of high-quality slabs. Thanks to the new process models and technological packages, it was possible to achieve the desired level of slab quality starting with the very first heat.

This paper describes the project and how it progressed, how the plant equipment was modified, the installation of back-up systems, and how the functionality of the slab caster could be extended. The revamp led to increased plant availability, casting of a broader product range and an optimized yield of the cast slabs. In addition to enhanced process stability and product quality, occupational health and safety at Slab Caster No. 3 were also improved. A selection of long-term quality-improvement and optimization measures are additionally outlined in this paper.



Modernization of Slab Caster No. 3 at Hüttenwerke Krupp Mannesmann, Duisburg-Huckingen, Germany

Ladle turret of the Arvedi ESP slab caster at Rizhao Steel, China

ARVEDI ESP'S CASTER SKILLS TO ENTER A NEW WORLD OF ENDLESS PRODUCTION

Paper number: 8
Principal author: Irene Watzinger

Thin-slab casting and rolling processes are well known and have been in continuous development since their introduction at the end of the last century. In an attempt to find the optimum configuration to be able to economically operate and fully load the rolling mill, several different concepts have emerged that include up to three casting strands fed into a single rolling-mill line. These different concepts are based on complex furnace constructions, which have numerous drawbacks. The key is to simplify all of these concepts to a single-strand concept. The main target is to ensure a stable and high mass flow.

Arvedi ESP technology represents the benchmark technology in this field. A steel mass flow of up to an annual throughput of 3 million t/a is possible thanks to fully endless operation and several other technological highlights implemented at Arvedi ESP casting machines. This paper focuses on the advanced mold system, including mold monitoring and mold-level stabilizing systems.

Arvedi ESP technology represents the benchmark technology in this field.

STUDY ON SPRAY COOLING FOR THE VOESTALPINE CC4 SLAB CASTER

Paper number: 24
Principal author: Dr. Josef Watzinger

The dual-strand casting machine CC No. 4 at the Linz steelworks in Austria is the company's oldest machine still in operation. It casts 225-mm-thick slabs comprising ultra-low carbon, low-carbon and HSLA (high-strength, low alloy) steel grades. Recently, edge defects began to appear on the hot strip that was produced from slabs cast on this caster, appearing along a strip-width range of around 1,000 mm to 1,200 mm when casting micro-alloyed construction steel. Such defects had not been seen on hot strip when rolling slabs from the other casting machines at the plant.

Primetals Technologies, in cooperation with voestalpine experts, carried out a comprehensive study of the entire air-mist spray-cooling process. The cooling setup and various operational adjustments were investigated. The spray performance of each nozzle was checked in a test facility of Primetals Technologies. During these tests, the water distribution across the slab width was simulated using the appropriate simulation tools. A realistic spray pattern for each cooling loop as well accumulated patterns at certain specific positions were established and subsequently reviewed. Exceptional situations arising from the collision of sprays with installed equipment were also taken into account in the nozzle tests and simulations.

Critical situations and issues that led to local overcooling could be subsequently identified, which were directly related to the above-mentioned quality issues. A stepwise improvement plan was then developed. Most of the major product quality issues were resolved with the implementation of the first short-term modifications.

Investigation of the spray performance of different nozzle designs

UNSTEADY BULGING COMPENSATION AT OUTOKUMPU TORNIO'S CASTERS 1 AND 2 – STABLE MENISCUS DURING CASTING OF FERRITIC STAINLESS STEEL

Paper number: 10
Principal author: Paul Felix Dollhaeubl

Process stability during continuous casting is essential for the production of high-quality stainless steels. In particular, the meniscus, which is the most sensitive zone of the entire strand, has to maintain a constant shape and steady position. The liquid core of the strand acts like a hydraulic hose, so each radial movement of the strand shell has an impact on the level of steel in the mold. Hence, strand-shell bulging between the containment rollers leads to a coupled effect of the transient strand volume and the position of the steel meniscus. The crucial factor is that mold-level fluctuations have an impact on the generated strand shell in terms of thickness variations. Ferritic stainless steel grades, which typically have a soft and creeping material behavior during casting, are known for their affinity for high and unsteady bulging.

The roller geometry of a casting machine also has an influence on bulging behavior. For instance, many consecutive identical roller pitches will lead to a superposition of the pumping effect of the roller pairs and an increased bulging tendency. Therefore, state-of-the-art slab casting machines have defined variations of the consecutive roller pitches within the caster segments. Slab casters with a single-unit casting bow are equipped with staggered rollers between the inner and outer bow due to the difference in the number of installed rollers. The offset between inner- and outer-bow rollers reduces the bulging tendency with this machine type.

At Outokumpu Tornio, both machine types, i.e., segmented casting bow (Caster 2) and single-unit casting bow (Caster 1), are in operation. Meniscus stability has been significantly improved with the installation of an unsteady-bulging compensation controller in both machines, which suppresses periodical mold-level fluctuations generated by unsteady bulging. This model-based controller is implemented as an add-on software package in the mold-level-control PLC as part of the LevCon technological package.

HIGH-SPEED CASTING AND THE INNOVATIVE WINLINK MINI MILL AT GPH BANGLADESH

Paper number: 21
Principal author: Gerold Schoeftner-Gruebl

WinLink is a pioneering technology from Primetals Technologies that allows both endless and semi-endless production of long products from liquid steel without interruption. The solution directly links a high-speed billet caster to a high-availability rolling mill by using an advanced induction-heating unit instead of a conventional billet-reheating furnace.

GPH Ispat Ltd. in Chittagong, Bangladesh, is the first customer where Primetals Technologies will implement the WinLink solution. The plant configuration allows full flexibility to run the mill in various production modes. One strand of the three-strand WinLink billet caster is linked directly to the rolling mill in the endless mode, which allows up to 70 t/h of rolled products to be produced at casting speeds of about 6 m/min without cutting and heat losses. The two additional billet strands are used for the production of about 50 t/h saleable billets, which are cooled on the cooling bed and rolled at GPH's existing rolling mill. This multi-strand configuration significantly improves the productivity of the plant by ensuring greater flexibility in the face of unpredictable market changes.

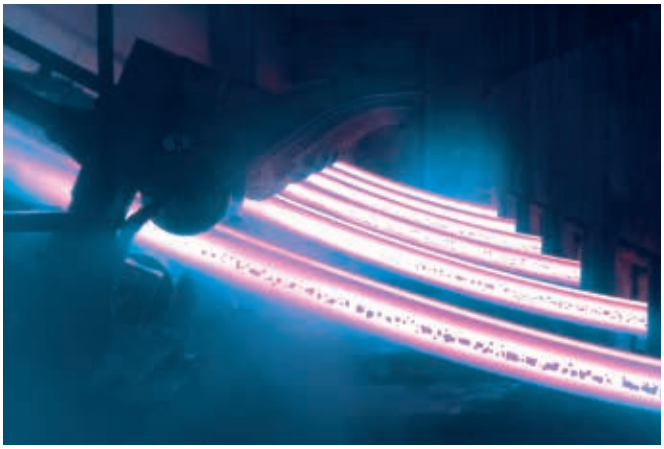
This paper provides an overview of different WinLink variants that are offered for production capacities of up to 640,000 t/a of rolled products. The technologies that will enable high-speed billet casting are also discussed.

The multi-strand configuration significantly improves the productivity of the plant by ensuring greater flexibility in the face of unpredictable market changes.

TECHNOLOGICAL SOLUTIONS FOR THE REVAMP OF LONG-PRODUCT CASTERS

Paper number: 23; **Principal author: Andreas Eichinger**

The modernized 5-strand billet caster in operation at ESF Elbe-Stahlwerke Feralpi, Riesa, Germany



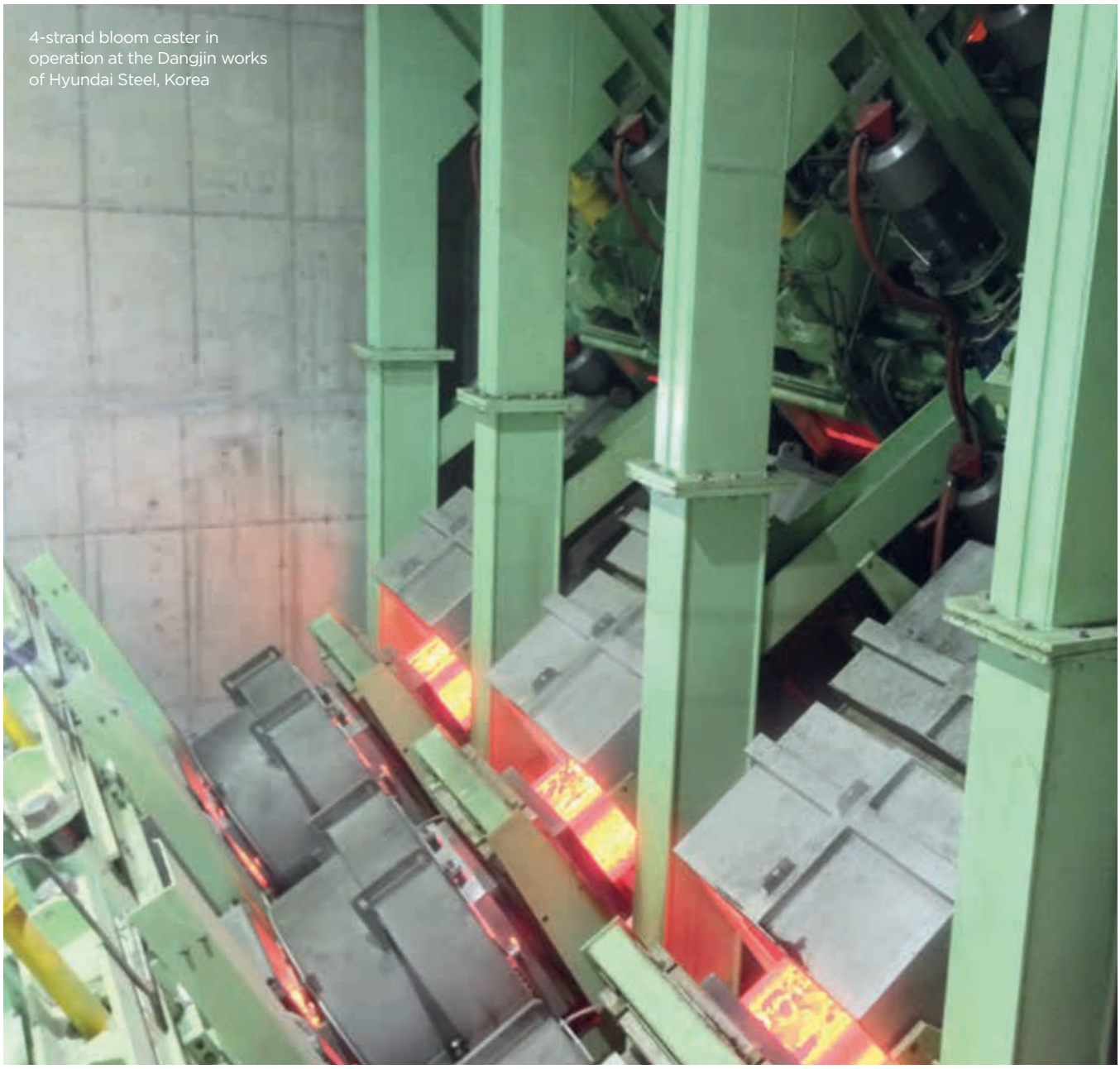
6-strand billet caster in operation at the Abinsk Electrometallurgical Plant

Primetals Technologies provides technological solutions for the revamp of long-product casters. This paper presents recent examples of successful project implementations at ESF Elbe-Stahlwerke Feralpi GmbH and OOO Abinsk Electric Steel Works Ltd (AEMZ), which underline the qualitative results that can be achieved within short project execution times.

EFS, located in Riesa, Germany, awarded Primetals Technologies a contract for the modernization of a 5-strand billet caster, which was restarted in 2015. The aim of the project was to increase productivity and to further improve the internal as well as the surface quality of the billets. The caster was equipped with a new machine head that included DiaMold mold tubes and retractable DynaFlex hydraulic oscillators, and the secondary cooling system was also upgraded. In order to optimize the shutdown period and keep installation time to a minimum, the new equipment was pre-assembled and tested.

OOO Abinsk Electrometallurgical Plant (AEMZ) is one of Russia's leading producers of reinforcing bars and other long products. The company operates an electrical steel plant and two rolling mills in Abinsk, which is located in the Krasnodar region of southern Russia. In March 2016, Primetals Technologies was awarded a contract to revamp the electric arc furnace, ladle furnace and the 6-strand billet caster.

The main project targets were to increase productivity, lower production costs, improve billet quality, and broaden the product scope with the casting of quality steel grades such as cord, spring, cold-heading and welding steel grades. Casting speeds will be increased to 5 m/min for 130-mm-square billet sections to enable AEMZ to expand the plant's annual production output to 1.5 million tons of billets. The casting of quality steel grades will be possible with the installation of stopper equipment, electromagnetic stirring systems, tundish shroud manipulators and automatic mold-powder feeders. The new machine head, which features a DiaMold high-speed casting mold, DynaFlex hydraulic oscillation units and electromagnetic stirring in the mold, will ensure a high quality of the cast billets. Furthermore, the new Level 2 automation system will safeguard consistency in the production of high-quality billets cast at high casting speeds.



4-strand bloom caster in operation at the Dangjin works of Hyundai Steel, Korea

LATEST INNOVATIONS IN BLOOM CASTING AT HYUNDAI STEEL DANGJIN

Paper number: 15; Principal author: Dr. Denijel Burzic

This paper provides an overview of the latest solutions implemented by Primetals Technologies for continuous bloom casters. The heavy-section bow-type bloom caster at the Dangjin works of Hyundai Steel Co., Ltd. in Korea serves as an example for the range of solutions and technological packages that are offered for quality steel producers. Bars and wires, which are rolled from the blooms, are used as the primary material for engine and gearbox parts by the Hyundai Motors Group.

The caster is equipped with mold-level control and an instrumented mold that features breakout prevention. Consistently high bloom quality is additionally supported by the combination of the following: air-mist spray cooling and interior-cooled rollers in the strand-guidance system; DynaGap Soft Reduction; and electromagnetic mold stirring and final strand stirring. Blooms are directly fed into the bar line while they are still hot. This not only saves energy costs during reheating, but also improves operating safety because there is no need for the use of cranes to handle the blooms. An inline bloom-quenching facility is foreseen for the production of special steel grades. An overview of the bloom-quality results achieved during the start-up of the Hyundai Steel bloom-casting machine is also presented in the paper.

This is the first plant of its type worldwide.

OPERATION RESULTS OF VERTICAL CASTING OF HEAVY ROUND BLOOMS AT ZHONG YUAN SPECIAL STEEL

Paper number: 27; **Principal author: Franz Wimmer**

A new vertical caster for the casting of special steel grades went into operation at Zhongyuan Special Steel Co., Ltd., in Jiyuan, China, in June 2015. The 2-strand vertical round-bloom machine has a casting capacity of up to 370,000 tons per year, which enables Zhongyuan to produce additional high-quality steel grades. The company previously only had an ingot-casting plant for the production of mainly steel forgings. A newly designed multi-roller driver unit provides for optimum support of the 120-ton strand during casting.

This is the first plant of its type worldwide. The new continuous caster is designed as a vertical plant with a height of 40 meters and a metallurgical length of 23 meters. It produces heavy blooms with diameters of 400 mm, 600 mm and 800 mm, and bloom lengths of between 2.5 m and 6 m. The maximum casting speed is 0.55 m/min. The caster is equipped with a straight DiaMold tubular mold that is 700 mm long. The DynaFlex tubular mold oscillator allows for flexible adjustment of oscillation parameters. Technology packages such as the LevCon mold-level control system and the Mold Expert breakout-detection system ensure trouble-free casting. An advanced air-mist secondary-cooling system, which includes the Dynacs 3D metallurgical cooling model and DynaJet cooling nozzles, is the basis for achieving optimum product quality.

The latest solution for heavy-bloom round casting and the corresponding operational results are presented in the paper to illustrate the special features of vertical bloom casting.

The 2-strand vertical round-bloom caster at Zhongyuan Special Steel Co., Jiyuan, China

MAINTENANCE OF CONTINUOUS CASTERS FOR HIGH-PRODUCT QUALITY: SIMPLE MEASURES AND ADVANCED TOOLS

Paper number: 11
Principal author: Dr. Martin Hirschmanner

The modern continuous casting machine is a highly complex mechatronic system where absolute precision is critical to ensure high-product quality and where equipment has to be designed to withstand harsh ambient conditions. These two requirements alone would be challenging, but in addition to that, operational costs have to be kept to a minimum to remain competitive under current market conditions.

Good maintenance procedures is a prerequisite for achieving high product quality at low cost during the operation of a continuous casting plant. The design of each component needs to be optimized for maintenance reasons. An example of such a component is the newly developed Single-Roll Dynagap (SRD) segment. Designed from scratch, the segment is a sophisticated system where the emphasis was placed on assuring a high degree of maintenance-friendliness. The single roller unit exchange contributes to improved plant availability.

Modern technologies subsumed under the buzzword “Industry 4.0” are applied to improve caster maintenance procedures. Examples include an intelligent equipment-tracking system, an automatic test procedure and a data-saving system to “smarten up” equipment. The combination of maintenance-friendly procedures, an efficient maintenance workshop concept, automated test procedures with built-in quality checks as well as efficient equipment reinstallation will ultimately improve product quality and reduce operational costs.

This paper includes several examples of how components of continuous casters can be exchanged quickly, checked for problems, repaired, tested and reinstalled. Examples of how the performance of a plant can be improved through technology consulting are also discussed.

3-D representation of a Single-Roll Dynagap (SRD) segment

Good maintenance procedures is a prerequisite for achieving high product quality at low cost during the operation of a continuous casting plant.

ROLLING TECHNOLOGIES FOR THE DIRECT STRIP-CASTING PROCESS

Paper number: 17
Principal author: Kenji Horii

The direct strip-casting process has attracted attention as a near-net-shape technology. Baosteel Group Corporation and Primetals Technologies have jointly developed technologies for a direct strip-casting process for carbon steel. A demonstration plant equipped with 800-mm-diameter and 1,340-mm-long casting rolls was installed in China and was put into operation in 2014. The stable casting and rolling of 1,340-mm-wide strips and long-term sequence casting of more than 350 tons have already been achieved.

This paper outlines the specific downstream equipment technologies for a direct strip-casting process such as an in-line reduction mill, a strip-cooling system and the carrousel-reel-type coiler. The paper also focuses on measures to achieve stable rolling conditions, such as with the use of the Dynamic Pair Cross Mill and strip-temperature control.

LIQUIROB – NEXT-LEVEL SHROUD MANIPULATION – FROM AN IDEA TO AN INDUSTRIAL SOLUTION IN THREE MAJOR STEPS

Paper number: 28; Principal author: Juergen Meisel

This paper explains how a robotic solution can be successfully implemented – from the initial idea to a working industrial solution. Primetals Technologies can refer to ten years of experience in the installation of the so-called LiquiRob robotic solution in the harsh environment of steelmaking plants. Driven by the desire to enhance an existing shroud-manipulation system, and based on the requirements of a well-known steel producer, the idea to connect the shroud to the ladle nozzle by means of a bayonet mechanism was born.

This paper reviews the development steps from the first simulations and prototype testing in the laboratory, the intensive system testing carried out under workshop conditions, and also the successful integration of LiquiRob at a slab caster. Furthermore, operational experience and the advantages of the LiquiRob solution are compared to other shroud-manipulation systems.

Operation of the LiquiRob robotic solution in the casting platform area

2-strand slab caster at Companhia Siderúrgica do Atlântico (CSA), Santa Cruz, Rio de Janeiro (RJ), Brazil. Primetals Technologies is responsible for a wide range of caster services at this plant.

ADVANCED MOLD COPPER PLATING – VARIABLE HIPER COATING

Paper number: 18; **Principal author: Franz Kolmbauer**

At the workshop of Primetals Technologies Brazil in Santa Cruz, Rio de Janeiro, mold coppers are electroplated for continuous casting by means of tank plating, i.e., submerging the copper in the bath of the plating solution. This is the most common method of plating and it is applicable for both broad-face and narrow-face copper plates.

Mold copper plates have a decisive impact on product quality as well as on the costs of maintenance and production. A comprehensive understanding of the operational influences on the plates and performance factors is the first step toward selecting the best copper-plating method. Variable Hiper Coat allows copper plates to remain in operation 50% to 100% longer than with conventional plating solutions, because the required hardness can be imparted to the copper plate where it is needed. Primetals Technologies offers a solution that meets and even exceeds the demands of today and tomorrow.

DynaJet Flex water-spray nozzle

DYNAJET FLEX – ULTIMATE FLEXIBILITY IN SECONDARY COOLING

Paper number: 6
Principal author: Thomas Fuernhammer

Cooling zones in casting machines are typically equipped with air-mist nozzles to enable a wide turn-down ratio (typically 1:9) from the highest to the lowest water-flow rates with a constant spray pattern. To prevent strand corner cracks, the zones are additionally split into center and margin cooling strips across the casting width.

DynaJet Flex from Primetals Technologies is a new cooling system that takes the discretization of cooling zones in casting machines to the next level. By using water-only nozzles, which can be driven with a pulse-width modulated signal, it is possible to extend the turn-down ratio from 1:9 to 1:15 – and higher. Simultaneously, operational costs can be cut by more than 70% owing to less air consumption compared to conventional air-mist nozzles.

The system can be installed and tested on a segment during a planned maintenance cycle. After reinserting the segment into the machine, the air for controlling the nozzles is activated. From this point, the segment is ready to operate in accordance with the casting width to ensure the optimal temperature of the slab in and across the casting direction. The DynaJet Flex nozzle is equipped with a robust standard flange so that the nozzle can be securely fixed to the segment. Different nozzle tips can be mounted onto the nozzle head to generate the required spray pattern.

This paper shows how a caster can be modernized with DynaJet Flex nozzles, how caster productivity is increased, and how operational costs can be reduced.

NEW GENERATION OF CONTINUOUS CASTING PLANTS WITH AN INTELLIGENT MANUFACTURING STRATEGY

Paper number: 196
Principal author: Johann Penn

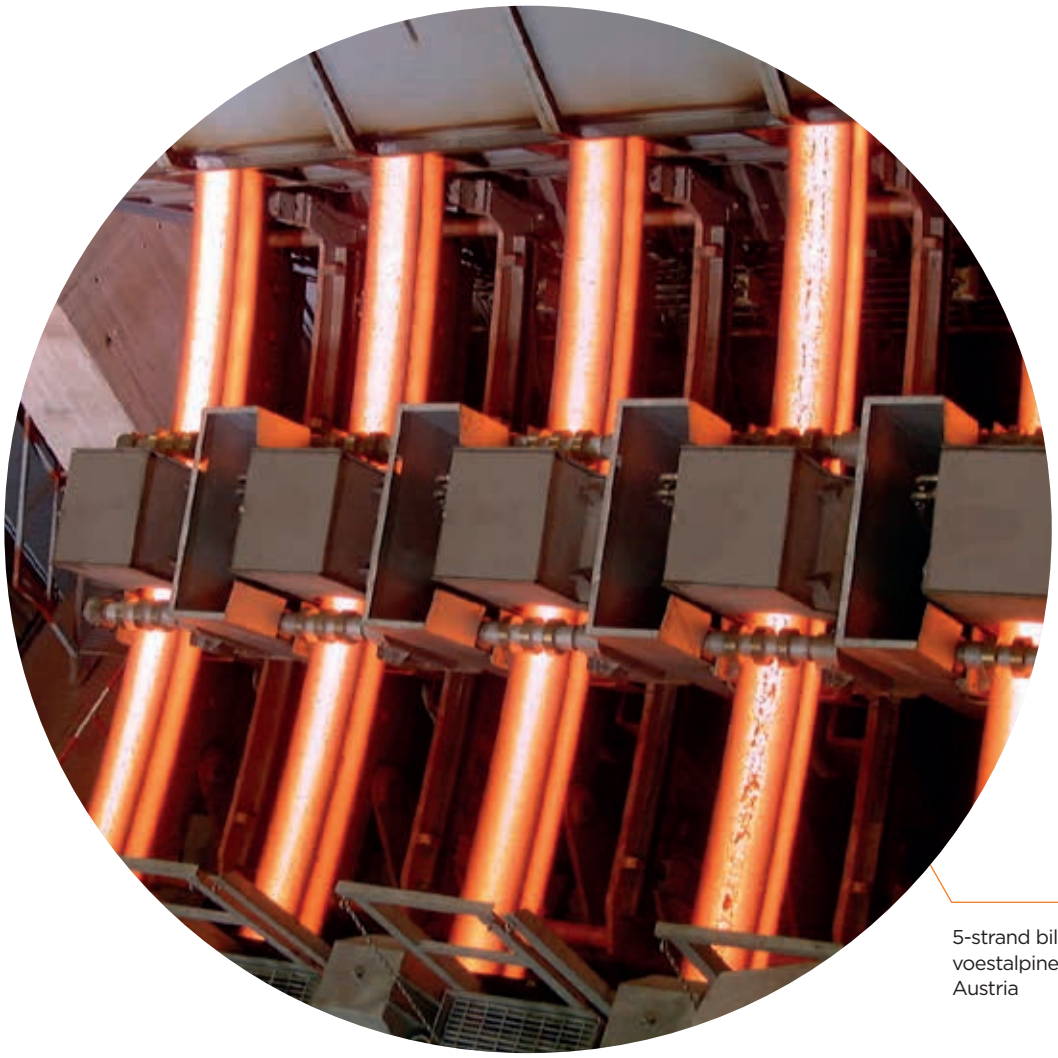
Changing market conditions demand the sustainable use of newly available technologies to support steel producers with highly flexible plant configurations and process tools. Investments are therefore targeted toward optimizing production costs and product quality while achieving a short-term return. The modular design of upgrading solutions allows the optimization of metallurgical processes to be individually configured, and takes into account a holistic overview of the steelmaking and continuous casting routes.

One of the most important developments in recent years is the integration of process parameters across the entire production route – from ironmaking up to strip finishing. This was also considered for continuous casting plants by using the steel chemical analysis data from secondary metallurgy as input parameters for the caster process model DynaPhase for modeling phase transformations. Consequently, the casting process can be controlled more predictably and with a high degree of accuracy. This also allows an exact determination of the final point of solidification for state-of-the-art soft reduction.

Recent developments have also focused on reducing energy costs on the one hand, while improving product quality on the other. This has led, for example, to the development of the completely new DynaJet Flex secondary-cooling system. This system no longer requires operation air and thus allows the cooling turn-down rate to be doubled. This contributes toward meeting the growing demands of special steel casting.

This paper features an overview of the above new developments in continuous casting during the last two years and the corresponding operational results. Highlights of the Industry 4.0 setup of caster process modeling and various plant configurations are also presented.

One of the most important developments in recent years is the integration of process parameters across the entire production route – from ironmaking up to strip finishing.



5-strand billet caster at voestalpine Stahl Donawitz, Austria

CCM 4.0 – DIGITALIZATION FOR INTELLIGENT PRODUCTION IN CONTINUOUS CASTING

Paper number: 16; **Principal author: Kurt Herzog**

Digital transformation brings about a structural change in automation – a transformation of process automation into a new and more efficient structure. Today's hierarchical automation pyramid is replaced by a flat structure of intelligent, flexible and autonomous units. It is important that the metals industry makes an active contribution to implementing digitalization in production plants throughout the entire value chain.

Digitalization for intelligent production synchronizes process, machine and product data for integration with business data in a "smart factory." "Smart services" enable data-based services such as predictive or data analytics. "Smart work" helps to improve maintenance and operation. This paper provides examples for the caster area.

The next stage of model-based process-automation control is to link the real-world plant with the virtual plant in a cyber-physical system. This is done by modeling and simulation of the casting process, for example by the integration of material properties according to their actual composition, strand-surface temperature profiles and dynamic soft reduction before the final point of strand solidification. The aim of digital transformation and the crosslinking of production is to ensure maximum flexibility and efficiency in production, high plant availability and superior product quality.

Primetals Technologies is committed to digitalization and to implementing the connected plant by continuously pushing latest innovations forward in close cooperation with its customers.

SEMI-CONTINUOUS CASTING TECHNOLOGY COMBINING TECHNOLOGICAL ADVANTAGES OF TWO DIFFERENT CASTING PRACTICES

Paper number: 9; **Principal author: Andreas Eichinger**

Bow-type continuous casters as well as vertical casting machines achieve high productivity and yield at high casting speeds. Nevertheless, for continuous production, the speed is limited by the metallurgical length of the machine and the required high cooling rates, which cause pronounced radial orientation of the crystallization front within the strand. Particularly for the casting of special high-alloyed steel grades, the strand center becomes prone to higher porosity and the formation of cavities.

Contrary to this, conventional ingot casting is characterized by low productivity and yield, and cooling takes place at low cooling rates. This low cooling rate results in an axial orientation of the crystallization front within the strand, and consequently to the best inner strand quality – especially for special high-alloyed steel grades.

The objective of semi-continuous casting technology from Primetals Technologies is to combine the benefits of ingot casting and continuous casting for the production of most special steel grades such as tool-, die- and stainless steels. Special attention is therefore placed on optimizing key equipment and component areas of the caster, such as the mold and oscillator, to achieve an optimum strand-surface quality and low operating expenditures (opex). Additionally, other proven continuous casting solutions and technologies are applied for special steel casting. This includes electromagnetic mold and strand stirring and the use of advanced process models such as DynaPhase and Dynacs 3D to dynamically control segmented heat zones for achieving the lowest possible cooling rates – the major benefit of ingot casting. This combination of these solutions leads to improved steel quality with respect to a symmetric crystal structure, the prevention of center cracks and cavities, and highest internal cleanness together with an optimized yield.

This paper outlines different aspects of semi-continuous casting machines for small and large strand sections. The resulting quality, yield, operation, investment and running costs compared to conventional continuous casting and ingot casting are also described.

The objective of semi-continuous casting technology is to combine the benefits of ingot casting and continuous casting for the production of most special steel grades.

CONTINUOUS CASTING HIGHLIGHTS OF PRIMETALS TECHNOLOGIES

- More than five decades of experience in the supply of continuous casting machines
- More than 1,700 continuous casting machine references worldwide
- More than 470 slab casters supplied worldwide since 1968
- 2,156 non-stop casting sequences with a 2-strand slab caster
- Up to 400 mm thick slabs cast in ultra-thick slab casters
- World's widest slab (3,250 mm) cast in a slab caster
- More than 2,500 installed square and round billet strands
- World's largest beam blank (1,024 mm x 390 mm x 90 mm) cast in a beam-blank caster
- 160 casters equipped with the Mold Expert systems for minimized strand breakouts
- World's leading supplier of secondary cooling systems and strand soft-reduction technology