WORLDWIDE LONGEST CONTINUOUS CASTING MACHINE FOR HIGHEST PERFORMANCE AT POSCO GWANGYANG WORKS CCP2-CCM3 / SOUTH KOREA[1]

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Abstract
The main target of revamping the CCP2 CCM3 slab caster was to increase production rates and improve slab quality as well as to achieve stable production conditions. From a metallurgical aspect, most attention was paid to facilitating high speed casting through the utilization of 3D Sprays – dynamic spray width adjustment system, automatic strand taper control with DynaGap SoftReduction® and the new DRI-Star rollers. To obtain best quality, the caster type was modified from a curved to a vertical bending type. The main production at CCP2 CCM3 is ULC and LC grades with a maximum casting speed of 2.7 m/min at a slab thickness of 250 mm and an annual production capacity of 3,500,000 tons per year for HR/CR coils. In addition to the metallurgical targets, POSCO also achieved the highest safety levels for continuous casting plants currently available with the new automation concept LiquiRob® in the tundish area. Together with the technological packages and process models, CCP2 CCM3 represents the most advanced continuous casting machine worldwide.
Key words: Caster; Ultimate productivity; Flexibility; Robot; Soft reduction.

MAIS LONGA MÁQUINA DE LINGOTAMENTO CONTÍNUO DO MUNDO PARA O MAIS ALTO DESEMPENHO POSCO GWANGYANG - CCP2-CCM3 – CORÉIA DO SUL

Resumo
A principal meta da reforma do lingotamento contínuo CCP2 CCM3 foi aumentar os níveis de produção e melhorar a qualidade das placas tanto quanto atingir condições estáveis de produção. De um aspecto metalúrgico, foi dada a maior atenção em facilitar a alta velocidade de lingotamento através da utilização do 3D Sprays - sistema de spray dinâmico de ajuste de largura, controle automático de afilamento do veio com o DynaGap SoftReduction® e os novos rolos DRI-Star. Para se obter a melhor qualidade, o tipo de lingotamento foi modificado de flexão curva para flexão vertical. A principal produção da CCP2 CCM3 são os graus ULC e LC com uma velocidade máxima de lingotamento de 2,7 m/min para espessura de placa de 250 mm e capacidade anual de produção de 3.500.000 t para bobinas HR/CR. Adicionalmente às metas metalúrgicas, POSCO também atingiu o mais alto nível de segurança para plantas de lingotamento contínuo disponíveis no momento, com o novo conceito de automação LiquiRob® na área de distribuidores. Juntamente com os pacotes tecnológicos e modelos de processo, a CCP2 CCM3 representa a máquina de lingotamento contínuo mais avançada do mundo.
Palavras-chave: Lingotamento; Produtividade máxima; Flexibilidade; Robô; Redução suave.

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1 INTRODUCTION

The main target of revamping the CCP2 CCM3 slab caster was to increase production rates and improve slab quality as well as to achieve stable production conditions. From a metallurgical aspect, most attention was paid to facilitating high speed casting through the utilization of 3D Sprays – dynamic spray width adjustment system, automatic strand taper control with DynaGap SoftReduction® and the new DRI-Star rollers. To obtain best quality, the caster type was modified from a curved to a vertical bending type. The main production at CCP2 CCM3 is ULC and LC grades with a maximum casting speed of 2.7 m/min at a slab thickness of 250 mm and an annual production capacity of 3,500,000 tons per year for HR/CR coils. In addition to the metallurgical targets, POSCO also achieved the highest safety levels for continuous casting plants currently available with the new automation concept LiquiRob® in the tundish area. Together with the technological packages and process models, CCP2 CCM3 represents the most advanced continuous casting machine worldwide.

The design, supply and installation of facilities were mainly done by the consortium of Siemens VAI Metals Technologies (Siemens VAI), POSCO E&C and POSCON. The project was realized within 18 months after signing of contract with a revamping period of three and a half months. Start-up took place on 15 November 2007, two weeks ahead of the original project time schedule.

The operational results and POSCO's experience with the new Siemens VAI technological packages of the CCP2 CCM3 caster are summarized in this report.

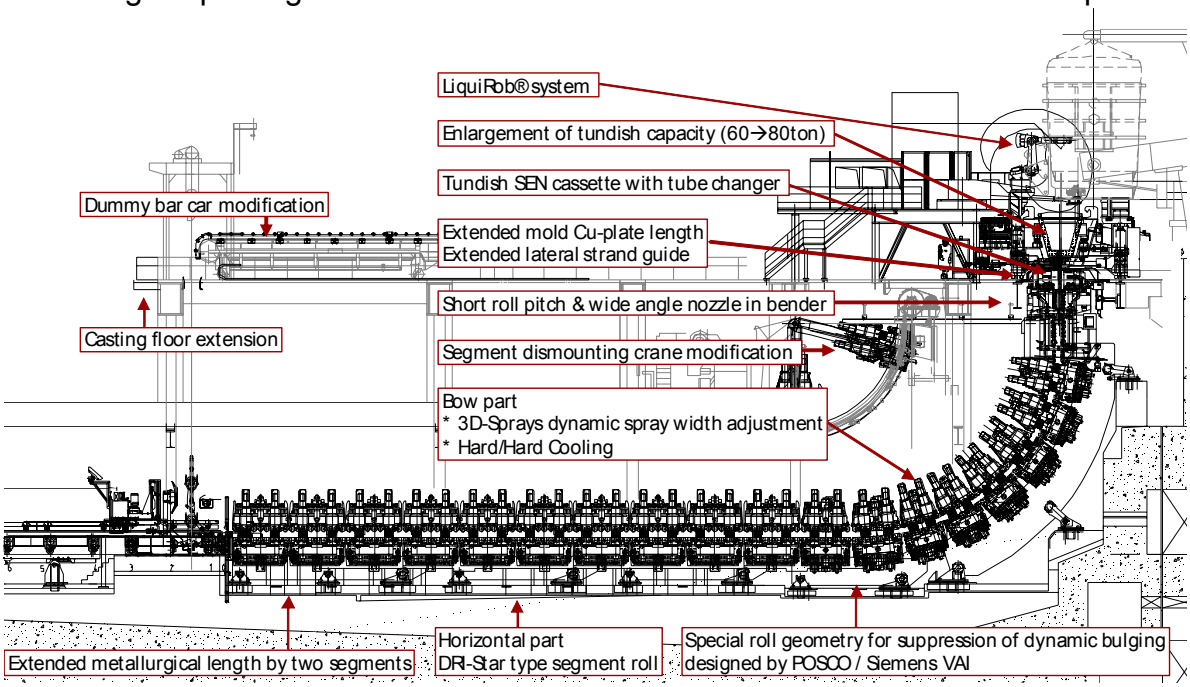

Figure 1: Overview of revamping

2 BASIC DATA

Main objectives of revamping:

- Vertical bending machine with segmented strand guide system
- Replacement of old facilities
  (start-up of old CCP2 CCM 3 : October 1992)
- Improvement of slab quality
  by minimizing center segregation through DynaGap SoftReduction technology
- New Level 1 and 2 automation systems
- Minimize manning requirement
  - Sampling, temperature measurement and tundish flux feeding by robot system LiquiRob
  - Fully automatic ladle shroud manipulator and SEN setting
- Optimization of maintenance work

Table 1: Basic data before and after revamp

Item	Before	After
Caster type	Curved	Vertical bending
Vertical length	-	2.75 m
Metall. length	42.1 m	47 m
Max. slab width	1600 mm	1600 mm
Max. casting speed	1.9 m/min	2.7 m/min
Machine radius	12 m	9 m
Slab thickness	250 mm	250 mm
Heat size	265 t	265 t

2.1 DynaGap SoftReduction

Like all other Siemens VAI slab casters recently installed at POSCO, the CCP2 CCM3 is also equipped with DynaGap SoftReduction technology in order to optimize internal quality by minimizing center segregation and center porosity of the slabs.
Soft reduction can be applied throughout the entire length of the machine, from segment 1 to segment 18. The typical reduction region is determined by a solid fraction from 50 % to 95 %.

2.2 3D Sprays – Dynamic Spray width Adjustment System

Siemens VAI has developed a moveable nozzle arrangement which allows the nozzle position to be adjusted in relationship to the slab width. This is accomplished by raising or lowering the nozzle arrangement in a slanted direction parallel to the

spray angle. If the casting width is decreased, the nozzles move closer to the slab surface and nearer to the slab center. This creates a smaller spray width. In the case of increasing slab width, the opposite occurs (Figures 2 and 3). The nozzle positioning is carried out in such a way that the spray water distribution is uniform and that a defined distance to the slab corner is maintained to avoid overcooling of the corners. Each strand segment is controlled by its own spray-width adjustment controller. This makes it possible to vary the non cooled area in casting direction.(1)
The 3D Sprays are linked with the Siemens VAI DYNACS® secondary cooling model, which enables an online calculation of the strand temperature profile with boundary conditions derived from the actual water flow rates, casting speed, steel grade, casting size and superheat temperature. The actual temperature is compared with the target temperature and new water setpoints related to the nozzle position and the actual spray density are calculated.

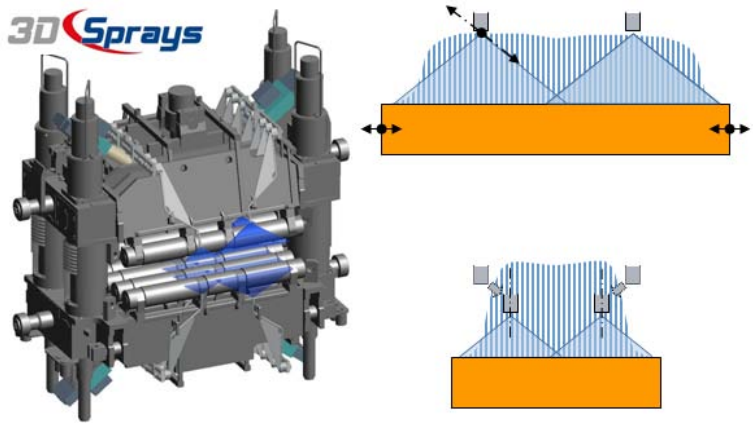

Figure 2: Basic operating principle of 3D Sprays showing the spray patterns and water distribution for wide and narrow slabs.

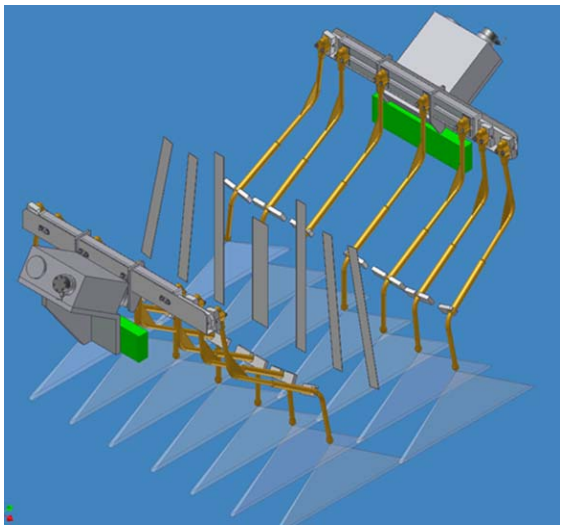

Figure 3: Arrangement of nozzles with spray headers and drive units.

Gwangyang's CCP2 CCM3 caster is equipped with 3D Sprays in the bow and straightening part. Together with a two step center/margin system in the bender this is the optimum solution for controlling slab corner temperature.
POSCO's hard cooling strategy is applied for special steel grades. In combination with 3D Sprays, the slab temperature can be decreased without the risk of overcooling the slab corners (Figure 4).

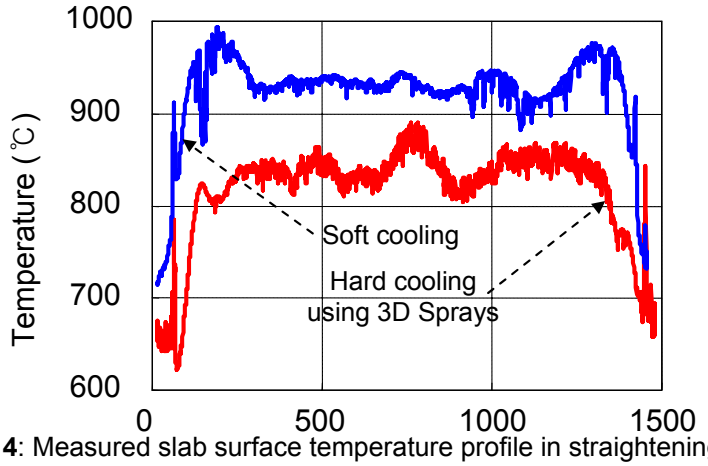

Figure 4: Measured slab surface temperature profile in straightening area.

Figure 5 shows the decrease in number and intensity of corner cracks when applying the hard cooling strategy.

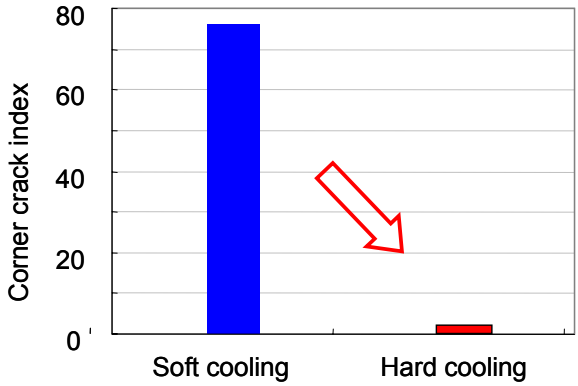

Figure 5: Corner crack index according to cooling pattern.

2.3 DRI-Star Rollers

At the CCP2 CCM3 Caster, all horizontal segments are equipped with DRI-Star rollers.

Following extensive investigations and field tests, an optimized solution for internal roller cooling was implemented in which cooling water from the roll center is directed to the peripheral zones of the roller. The water then flows through a series of near-surface channels drilled through the roller body, effectively cooling the roller surface to an acceptable temperature range (Figure 6).

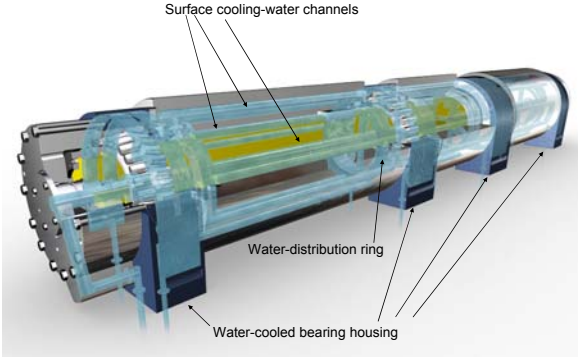

Figure 6: DRI-Star roller

Trial casting showed that slab surface temperature at the machine end increased significantly when the spray cooling water was turned off and the rollers were just internally cooled and no external spray water was applied.

2.4 LiquiRob

In a steel works environment, particularly where liquid hot metal is produced or manipulated, operators are exposed to dangerous working conditions. For example, the caster platform is especially unsafe because of the large number of potential accidents that can occur. These include tundish or mold steel overflows, steel splashing, leakages and breakages or other material defects. For this reason, Siemens VAI developed a robot system named LiquiRob, which automatically carries out manual tasks on the caster platform for the entire casting sequence. This allows operators to supervise casting conditions and operations safely from the control room. [(2)]

The first industrial application of LiquiRob was at the Gwangyang CCP2 CCM3 caster at POSCO's Gwangyang works. It is designed to perform a multitude of functions in the tundish area:

- temperature measurement
- sampling
- tundish-powder dosing

The action radius of LiquiRob was maximized through the installation of the robot on a rotating moving unit.

The robot unit is designed and well protected for operation in the harsh environment of a steel mill, thus reducing maintenance requirements to a minimum (Figure 7).

Figure 7: LiquiRob in operation.

LiquiRob is included in POSCO's Level 1 and Level 2 automation system. Figure 8 shows the Level 2 HMI for robot control, which allows for semi-automatic as well as full-automatic control of the robot movements.

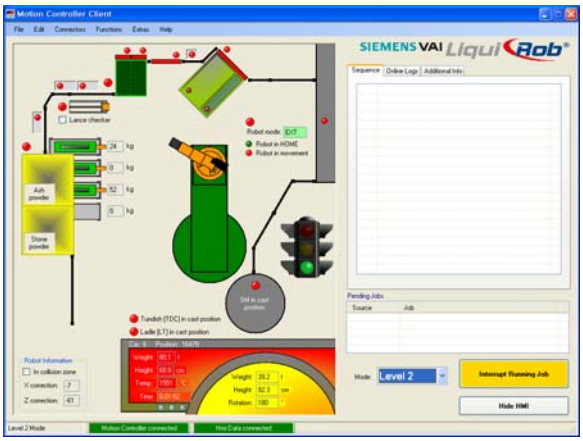

Figure 8: LiquiRob HMI system overview.

2.5 LevCon 2.0 Mold Level Controller

LevCon 2.0 mold level controller is a further development of the well proven LevCon mold level controller, which has been successfully applied at many casters worldwide.[3]
Among others LevCon 2.0 contains the following new features.

2.5.1 Plant gain model

An important parameter for the controller is the actual 'plant gain' of the mold level control loop. The plant gain is the relation ship between slide gate opening to mold level speed.
A plant gain model is included in the LevCon 2.0 controller which adapts the plant gain to the casting dimension.

2.5.2 Surface wave model

The excitation of surface waves is the major limiting factor for the controller performance. The LevCon 2.0 loop shaper removes this limitation but needs the information of the resonance frequency of the surface waves.
With the surface wave model the resonance frequencies of the surface waves are calculated for the current casting dimensions. These values are used as input parameters for the loop shaper.

2.5.3 H∞ loop shaper

The aim of the H∞ control algorithm is to find the controller which minimizes the infinity norm of the control error (mold level deviation) while the infinity norm of the control effort (slide gate movement) stays within certain limits.

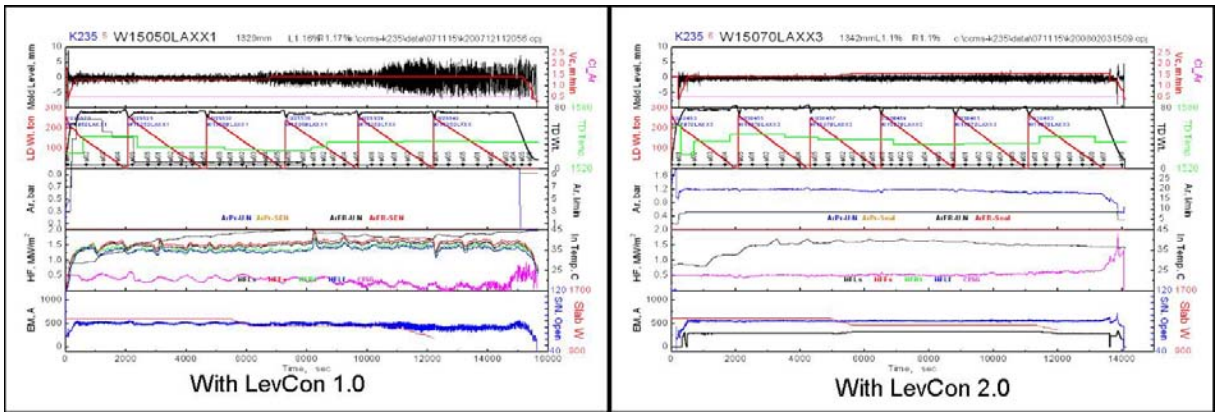

Figure 9: Mold level control with LevCon 1.0 and LevCon 2.0.

Figure 9 shows the mold level performance with LevCon 1.0 compared to the LevCon 2.0 system when casting a medium carbon steel grade.

3 OPERATIONAL RESULTS

During start-up of the caster, the maximum casting speed was increased to 2.7 m/min, which represents a new world record in casting speed for a 250 mm thick slab (Figure 10).

In order to reach this speed, all systems had to work properly. A special cooling concept, the so-called hard/hard cooling concept was applied. This concept results in a solidification factor of approximately 31 mm / √min. Only with this high solidification factor was it possible to cast 2.7 m/min at the given containment length of 47 m. Moreover a special casting powder and a special oscillation practice were used.

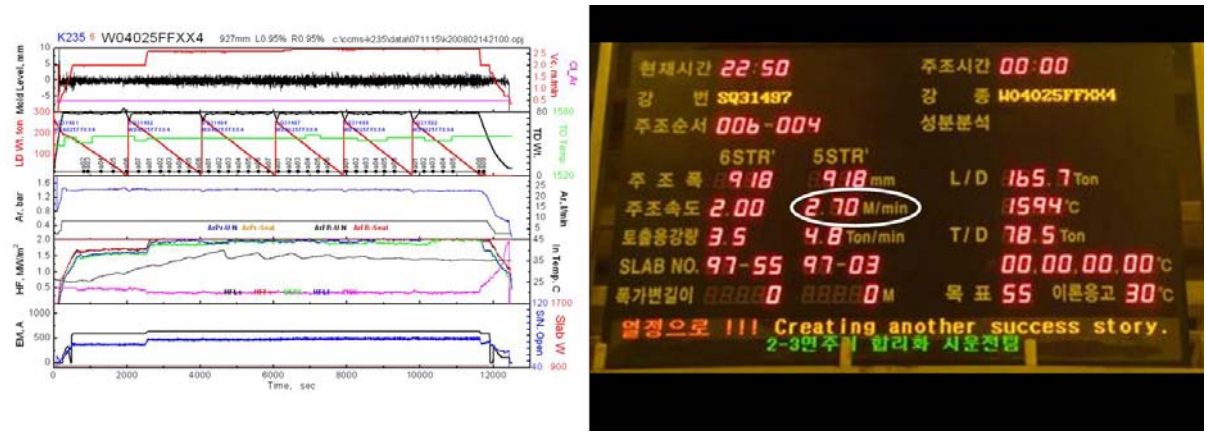

Figure 10: Reaching casting speed of 2.7 m/min

Stable casting operation was demonstrated by casting 30 heats in sequence by utilizing SEN changing equipment as well as tundish fly capabilities (Figure 11).

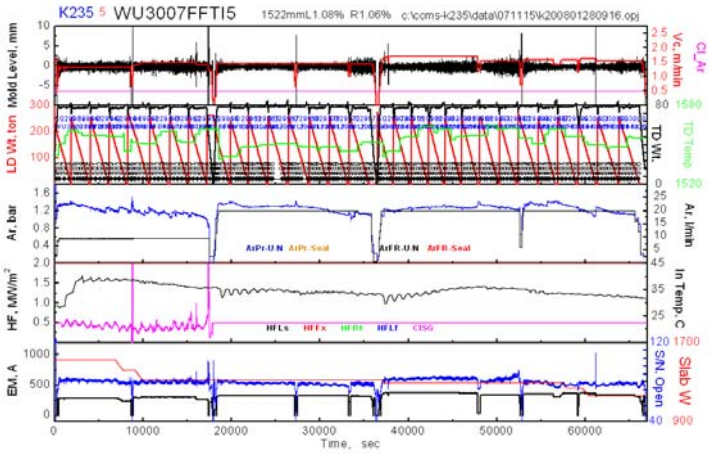

Figure 11: Operational result – 30 heats in sequence with 2 tundishes.

4 CONCLUSION

CCP2 CCM3 represents the most advanced continuous casting machine worldwide. DynaGap SoftRedution and 3D Sprays as well as LevCon 2.0 mold level control are the basis for best quality. Fully automatic and long sequence casting is achieved by advanced automation systems in the mold area and by utilizing the LiquiRob system. When applying POSCO's hard/hard cooling concept, a new world record for casting 250 mm thick slabs was possible.

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