SIEMENS VAI'S NEXT GENERATION CASTING TECHNOLOGY FOR ULTIMATE PRODUCTIVITY AND FLEXIBILITY [1]

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Abstract
Production flexibility is important for producers that supply markets with varying product demands, or where new market possibilities are being tapped. On the other hand, higher production rates enable producers to increase their contribution margin and profit. Siemens VAI, the technology leader in the field of slab casting, has recently developed the Next Generation Caster for both ultimate productivity and flexibility. Quick casting thickness adjustment on demand increases machine availability and Siemens VAI´s flexible strand guidance allows for inline thickness change from the mold to the last segment. With the use of the SIMETAL^{CIS} 3D Spray width adjustment system, highest surface quality is ensured for a larger product spectrum. In combination with SIMETAL^{CIS} DynaGap Soft Reduction, stable internal quality can be achieved for varying casting speeds. The new European standard for machine safety focuses on further reducing hazardous situations during the operation of casting machines, forcing plant builders to carry out risk assessments in order to ensure that casting machines comply with all relevant safety requirements. Siemens VAI´s answer to these safety issues is SIMETAL^{CIS} LiquiRob, the casting floor robot that performs tasks in hazardous areas. Some of these tasks include ladle slide gate cylinder connection, ladle shroud manipulation, and temperature and sample measurement. The paper describes in detail the latest Siemens VAI developments for the Next Generation Caster.
Key words: Caster; Ultimate productivity; Flexibility.

PRÓXIMA GERAÇÃO EM TECNOLOGIA DE LINGOTAMENTO CONTÍNUO DA SIEMENS VAI PARA PRODUTIVIDADE E FLEXIBILIDADE MÁXIMOS

Resumo
Flexibilidade de produção é importante para produtores que suprem mercados com variada demanda de produtos, ou onde novas possibilidades de mercado estão sendo vertidas. Por outro lado, níveis mais elevados de produção possibilitam aos produtores aumentarem a sua margem de contribuição e seu lucro. Siemens VAI, a líder tecnológica no campo de lingotamento contínuo de placas, desenvolveu recentemente a Nova Geração de Lingotamento Contínuo para produtividade e flexibilidade máximas. Ajuste rápido de espessura de lingotamento sob demanda aumenta a disponibilidade de máquina e orientação flexível do veio da Siemens VAI permite a troca contínua de espessura do molde até ao último segmento. Com o uso do sistema de ajuste de largura - SIMETAL^{CIS} 3D Spray, a mais alta qualidade superficial é assegurada para uma maior gama de produtos. Em combinação com SIMETAL^{CIS} DynaGap Soft Reduction, a qualidade interna estável pode ser alcançada para várias velocidades de lingotamento. O novo padrão Europeu para segurança de máquina objetiva a redução das situações de risco durante a operação das máquinas de lingotamento, forçando os construtores de plantas a determinarem as taxas de risco a fim de assegurar que suas máquinas atendam a todos os quesitos relevantes de segurança. Resposta da Siemens VAI para estas questões de segurança é o SIMETAL^{CIS} LiquiRob, o robô da plataforma de lingotamento que realiza atividades em áreas de risco. Algumas destas atividades incluem a conexão do cilindro da válvula gaveta, manipulação da válvula longa, medição de temperatura e tomada de amostra. Este trabalho descreve em detalhe o último desenvolvimento da Siemens VAI para a Próxima Geração em Lingotamento Contínuo.
Palavras-chave: Lingotamento contínuo; Produtividade; Flexibilidade máxima.

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1 INTRODUCTION

The very first attempts in Continuous Casting can be traced back to the mid-1880's and to pioneering work for Carbon Steels in 1940. Thanks to the development of oscillation by S. Junghans and the introduction of the negative strip by Iain Halliday in the 1950's, casting speeds could be increased to realistic values allowing to raise productivity of casters.(1)

"A continuous casting plant to produce one million tonnes of slabs per annum (1 mtpa) – this is no idle thought and exemplifies in the simplest words the threshold position today of the rapidly developing field of continuous casting of steel", were Iain Halliday's opening statements of the AIME Meeting 1961 in Detroit, USA, which no-one would any further question more than 40 years later. Today, caster production between 1,0 – 1,5 mtpa per strand are state-of-the-art and are achieved by steel-in-the-mold time of more than 80% related to calendar time in integrated steel plants.

Siemens VAI investigated the crucial question to further raise caster production beyond the 2,0 mtpa threshold per strand and developed several technologies to achieve such ambitious goals, which are described in detail thereafter.

2 TRENDS IN CASTER PRODUCTION

Today, typical conventional casting speeds are between 1,0 -1,5 m/min for slabs of 200-250 mm.

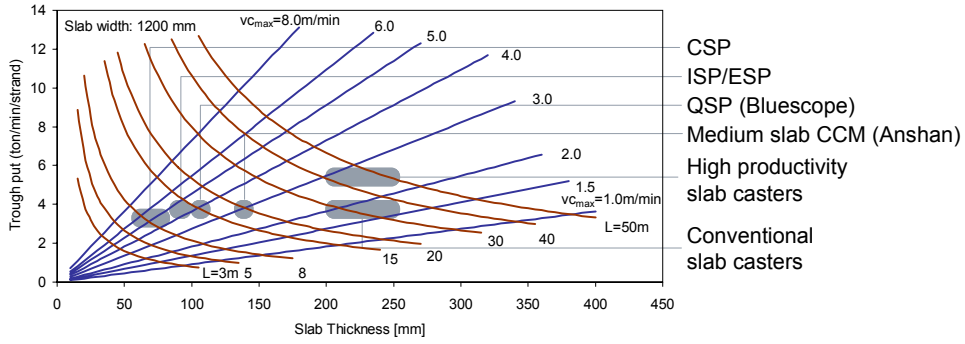


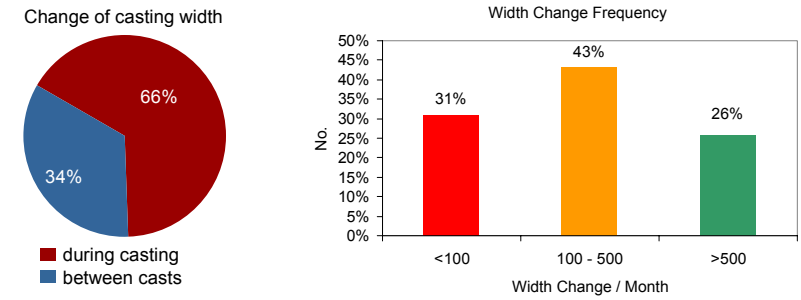
Figure 1: Caster production vs. casting thickness

As depicted in Figure 1 this leads to typical output rates of about 200 t/h per strand.(2,3) The metallurgical length is designed accordingly and operational practices like SEN and tundish changes on-the-fly are well known. Thin slab casters require to run about three or four times the speed to achieve about same productivity, however higher production are barely possible due to its physical and metallurgical machine limitations, which is less the case for medium slab casters.

Despite those limitations in machine design and metallurgy, economical investigations suggest that increase in caster productivity beyond today's production rates will result in reduced production costs and short ROI periods. This attracts investors hence production increase must not be compromised by the achievable quality or operational capabilities. One main lever is the increase in steel-in-mold time and as such the maximisation of caster utilization plays an important role to further raise production levels.

In order to achieve such deviating goals careful consideration of today's benchmarks regarding operational behaviour has to be carried out first.

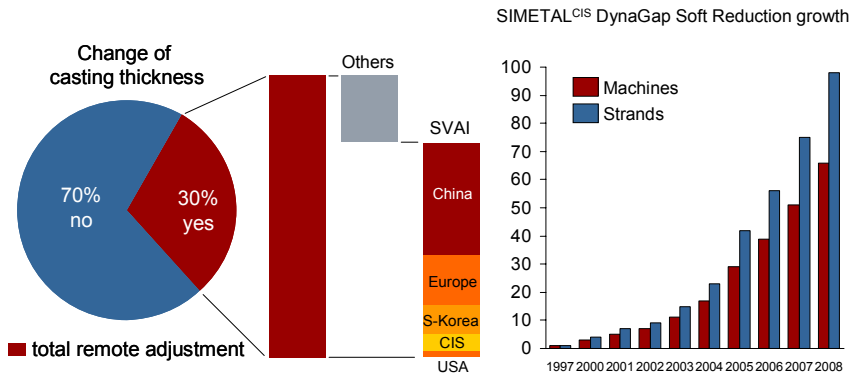
As one example, in Figure 2 casting width changes on-the-fly are plotted. More than 2/3 of the slab casters have the equipment to perform online width changes to follow the rolling mill width schedule, however only few machines utilize online changes to the full extent as the investigation shows. Some of the casters run only few width changes in short sequences or have sizing presses in the mill to cope with varying width demands of the customers. Others however run long sequences and make full use of their online change capabilities.



Source: VDEh Plant Facts (EU 25 plus Turkey)

Figure 2: Width change capabilities of slab casters[4]

Another example can be seen in figure 3 whereby more than 70% of slab casters do not have the capability to change the casting thickness. Most casters operate on single thickness even though equipment would be available to produce the "optimum" casting thickness required for the rolling process to cope with restrictions in the rolling process (e.g. achievable HRC thickness of hard grades) or the optimum metallurgical demands (e.g. reduction ratio for plate grades). Interestingly, most of the new casters built in Asia have automatic thickness change capabilities.



Source: VDEh Plant Facts (global), Siemens VAI MT

Figure 3: Thickness change capabilities of slab casters

Those 2 examples exemplify the huge potential to further boost capacity by improving machine's flexibility and usage of all operational features available on the market, today.

3 ECONOMIC CONSIDERATIONS

Before explaining further details of the technical/technological solutions to achieve 4,0 mtpa production on one caster, Siemens VAI would like to demonstrate its economical advantages by the following study. Two cases have been investigated to compare typical scenarios, which operators face when running new investment

considerations: In the first case you replace two 2-strand casters, in the second case you install a new one 2-strand high-production caster.

3.1 Case 1: Replacement of Two 2-strand Casters (Brownfield Investment)

A plant is operating two aged 2-strand casters, each producing 2 mtpa of slabs. Maintenance and production costs are rather high compared to state-of-the-art slab casters and product quality standards of today's market demands cannot be met fully. Operational flexibility is low.
The replacement of one old machine by a modern high-productivity slab caster would have following advantages:

- production capacity of 4 mtpa on one machine
- reduced operation cost
- reduced maintenance cost
- yield increase
- product quality improvement
- increased operational flexibility.

Below graph shows the caster implementation sequence anticipated during the outage. During ramp-up of the new machine to 4 mtpa, the remaining old machine will be consequently ramped down because of no additional liquid steel production.

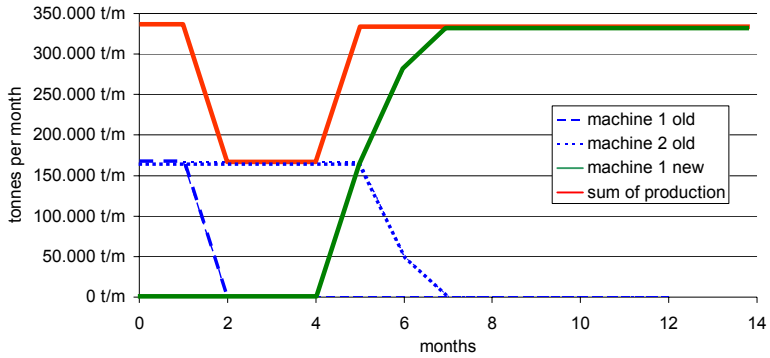


Figure 4: Production development – case 1

The replacement of one machine would cause a production loss of approximately 500.000 t for a 3 month period, if the caster is placed at the position of one existing old machine, which is idled. This loss of production is allocated 100% to the caster investment payback calculation as a very conservative scenario. Real operation will cut this loss by slab pre-production before caster replacement starts or slab purchases for compensation of production loss.
An evaluation model is calculated with following input parameters:

Table 1: Calculation model parameters

	2x2 slab old	Replacement to1x2 slab new
Investment	existing	100%
Caster yield	97%	98,5%
Operating staff (4shift)	100%	70%
Maintenance staff (4shift)	100%	60%
Specific maintenance cost (equipment)	100%	66%
3 months production loss due to caster exchange	none	500,000 t

Additional input figure into the model is the achievable higher contribution margin caused by better product quality, e.g. improvement of product surface, more homogeneous inner structure of slabs etc. Four different scenarios are considered:

Scenario 1: no increase of sales revenues
Scenario 2: 20 EUR/t higher sales revenues
Scenario 3: 40 EUR/t higher sales revenues
Scenario 4: 40 EUR/t higher sales revenues and purchase of 500.000 t of slabs to compensate the production loss (additional cost of 25 EUR/t)

Below diagram shows the additional cash flow of a new investment relative to the existing plant varying with the achievable higher sales revenues. The break even points are the intersections of cash flow lines with zero line.

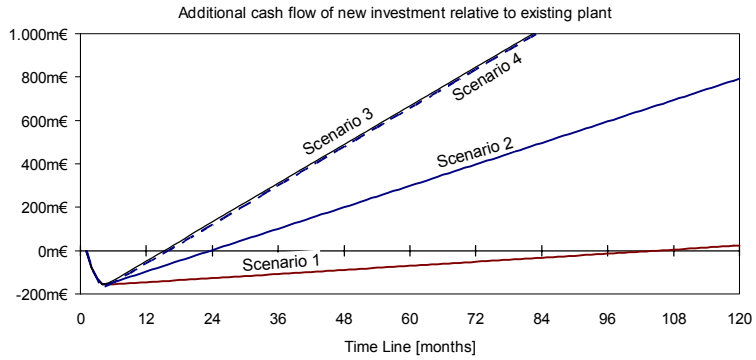


Figure 5: Cash flow development – case 1

With improved product quality and increased slab sales prices a reasonable quick return on investment will be achieved in less than two years. If the loss of sales revenues by duration of shutdown will be reduced by additional production and/or purchase of slabs, the payback period will be shortened significantly too.

3.2 Case 2: Two 2-strand Casters vs. One 2-strand high-production Caster (Greenfield Investment)

For a greenfield investment a decision has to be made, whether the installation of two 2-strand casters with a production of 2 mtpa each or one high-productivity caster for 4 mtpa shall be considered. It is assumed that both configurations ensure full flexibility at full production capacity and are state-of-the-art machines.
The following input parameters for the ROI model are considered:

Table 2: Calculation parameters for ROI model

	2x2 slab 4 mt	1x2 slab 4 mt
Investment	100%	65%
Caster yield	98%	98,5%
Operating staff (4 shift)	100%	70%
Maintenance staff (4 shift)	100%	60%
Specific maintenance cost (equipment)	100%	100%

Below diagram shows, that an annual production of 4 mt on a single machine has significantly lower specific production cost compared to a two caster configuration. It can be furthermore seen that the break-even point for a high-productivity caster compared to the two caster configuration is already achieved with annual production

of 2,3 mt. The payback period of the high productivity caster is 37% shorter compared to the 2x2 strand slab caster configuration.

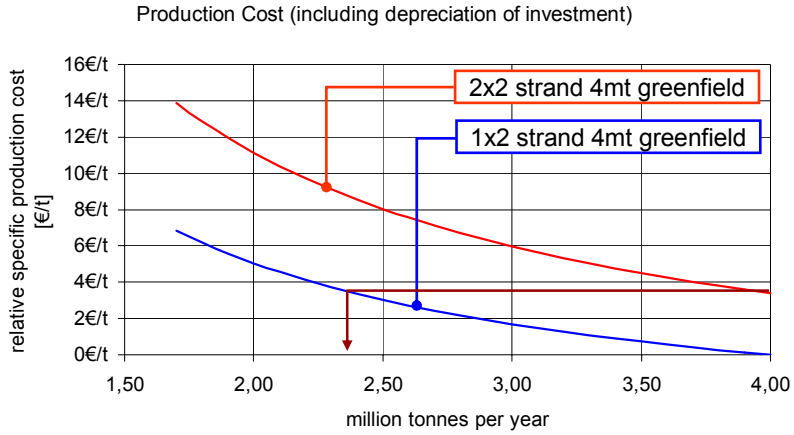


Figure 6: Production cost comparison – case 2

4 SOLUTIONS FOR HIGHER PRODUCTIVITY AND FLEXIBILITY

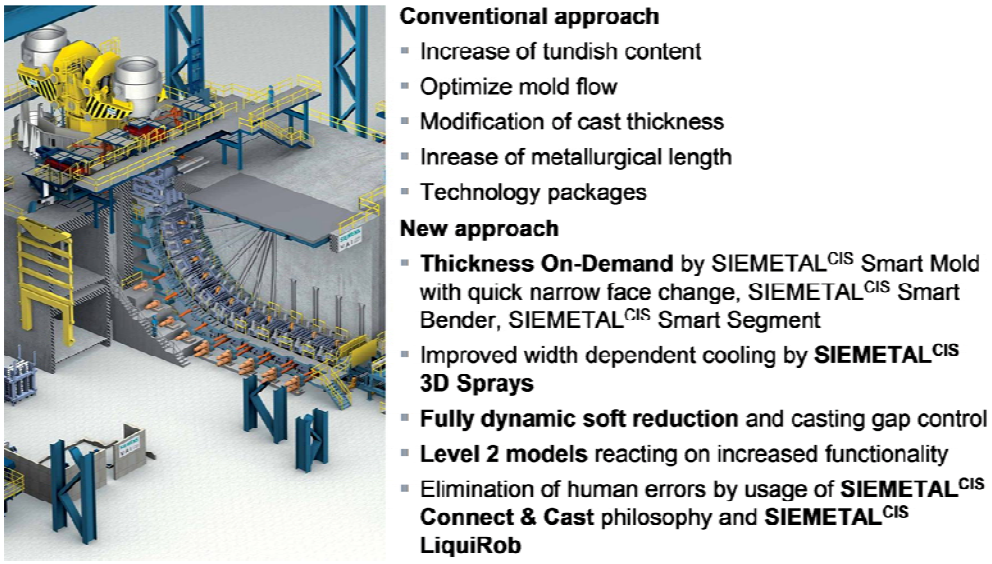


Figure 7: Solutions to increase productivity

If one is asked to design a caster for higher production rates – e.g. 300 t/h per strand - the conventional approach suggests an increase in tundish content, optimization of mold fluid flow as well as modification of casting thickness, casting width and metallurgical length. The consideration of caster flexibility to increase steel-in-mold time as one major cornerstone to further boost productivity is barely touched, however essential to achieve the goal.
Despite above Siemens VAI strongly believes that higher production rates can only be achieved by the additional introduction of new technologies as shown in figure 7.

4.1 New Approaches for Higher Production

4.1.1 Thickness on demand

Thickness on Demand – The combination of SIMETAL^{CIS} Smart Mold with inline exchangeable Narrow Faces, the SIMETAL^{CIS} Smart Bender technological package, and the rigidly designed SIMETAL^{CIS} Smart Segment enables fast slab-thickness

changes to be carried out through quick inline narrow face exchange and remote adjustment of the roller gap in very short time during restranding.

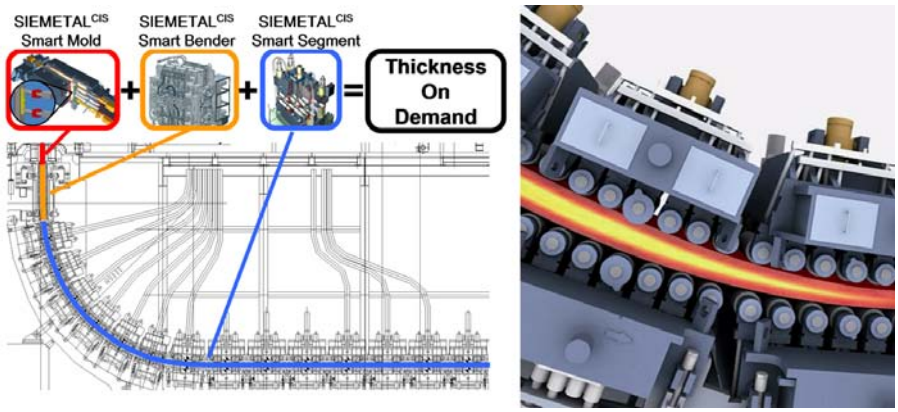


Figure 8: Thickness on demand technology

SIMETAL^{CIS} Smart Mold with inline exchangeable Narrow Faces is characterized by a low-weight yet rigid, cassette-type mold design with a reduced number of operational exchange parts (figure 9). The new quick exchange narrow faces allow in-machine cast thickness changes. When integrated with SIMETAL^{CIS} DynaWidth hydraulic mold-width adjustment system, fast and automatic slab-width changes are possible without the need for casting speed reductions to achieve shortest possible slab transition lengths. SIMETAL^{CIS} Smart Molds for more than 90 casters have been sold and 2 orders have been booked for the new quick exchange technology already.

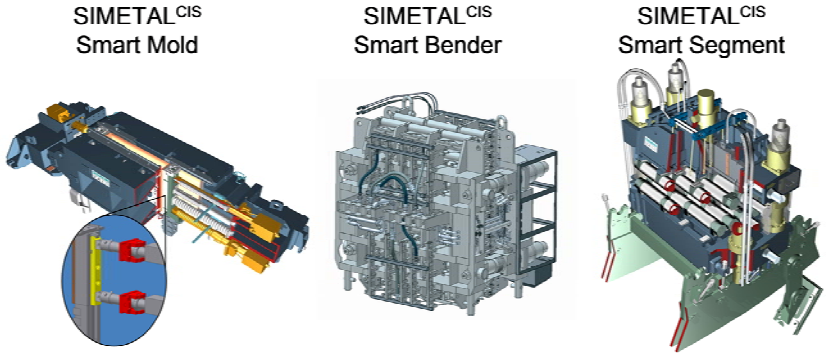


Figure 9: SIMETAL^{CIS} Smart Mold with quick narrow face change, SIMETAL^{CIS} Smart Bender, SIMETAL^{CIS} Smart Segment

The SIMETAL^{CIS} Smart Bender, a remotely adjustable first caster segment which allows quick strand-thickness changes to be carried out offers major operational benefits for producers requiring frequent slab-thickness changes and caster productivity at a high level. This proven technology is already in operation and sold for further machines (Figure 9).
SIMETAL^{CIS} Smart Segments – In addition to remote-changes of casting thickness between casts the SIMETAL^{CIS} DynaGap Soft Reduction is featured in combination with dynamic cooling model SIMETAL^{CIS} Dynacs. Siemens VAI has sold almost 70 machines with this new technology since 1997 (Figure 9).[(5)]

4.1.2 Improved heat removal by SIMETAL^{CIS} 3D Sprays

A new important technological feature for optimum product quality at highest casting speeds for a broad spectrum of width ranges and steel grades is a fully dynamic spray width adjustment system, Siemens VAI´s patented SIMETAL^{CIS} 3D Sprays.(6) This system was developed to ensure optimum heat removal of slab, but at the same time to avoid any overcooling of the slab corners (Figure 10).

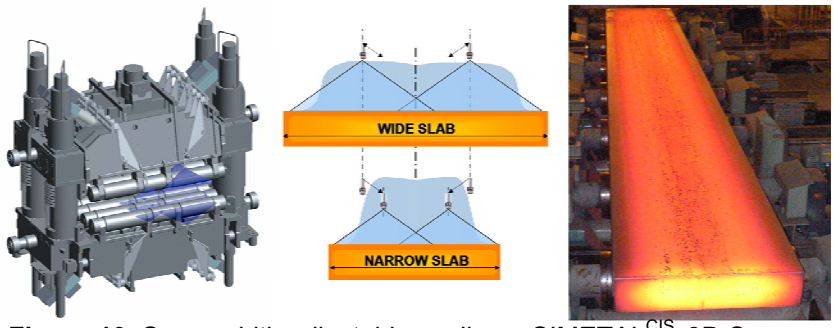


Figure 10: Spray width adjustable cooling – SIMETAL^{CIS} 3D Sprays

The well protected SIMETAL^{CIS} 3D Sprays are mounted on movable racks with position controlled hydraulic cylinders to allow them to follow the slab width in a continuously adjustable way, ensuring the optimum water distribution over the slab width. This technology has been industrially proven on a high capacity caster in Asia and is already sold for further machines.

4.1.3 Elimination of the human errors

To support rapid ramp-up curves and to reduce accidents by human errors Siemens VAI has developed Connect & Cast solutions and the SIMETAL^{CIS} LiquiRob casting platform.
Connect & Cast solutions are the basis for rapid plant start-ups.(7)

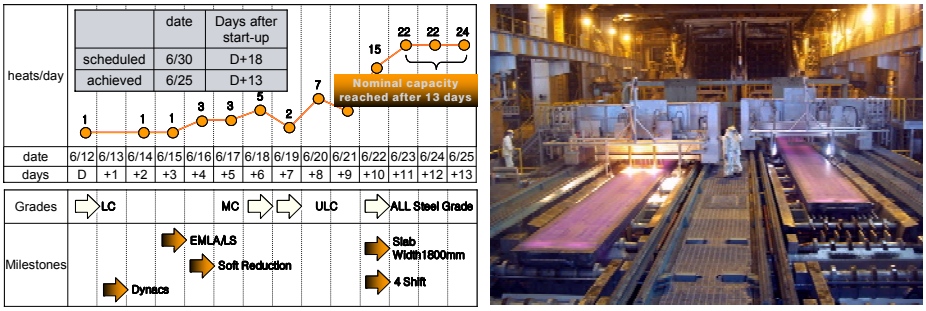


Figure 11: The Connect & Cast solution – Example POSCO Gwangyang CCM 1-3

Fully integrated engineering processes and procedures, from the start of a project to its completion, is the key for optimum plant design, equipment and system integration and reliable process operations. As demonstrated in numerous plants the nominal capacity could be achieved in a very short time (Figure 11).
With SIMETAL^{CIS} LiquiRob, patented engineering solutions are combined with the reliability of industrial robots, allowing casting personnel to monitor the entire casting process from a safe distance.(8) With the exact reproducibility of each operational task and the possibility to record all executed tasks automatically the robot contributes to improved cast product quality as well as to total quality control. The first SIMETAL^{CIS} LiquiRobs were put into operation in 2007.

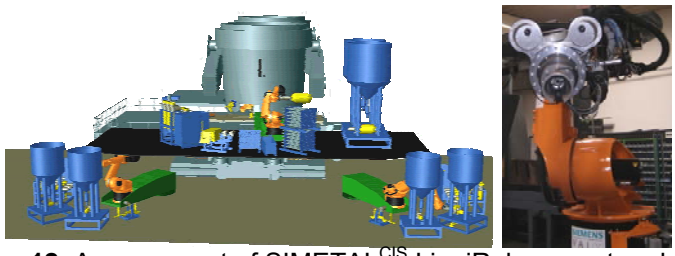


Figure 12: Arrangement of SIMETAL^{CIS} LiquiRob on caster platform

5 CONCLUSION

Siemens VAI investigated the economical benefits of a novel high productivity slab caster, which allows a substantial higher production rate to be achieved through increase of steel-in-the-mold time and casting speed. This caster can be installed in brownfield and greenfield investments with large economical advantages which lead to reduced ROI and less production costs.
This new slab caster configuration has a longer metallurgical length for increased casting speeds, new mechatronical packages like SIMETAL^{CIS} 3D Sprays, SIMETAL^{CIS} DynaGap SoftReduction, SIMETAL^{CIS} LiquiRob etc. to provide “just-in-time” thickness change on demand, to increase the operational flexibility and support top quality slab production together with Siemens-VAI's proven Connect&Cast philosophy.

REFERENCES

1 Wolf, M. M. History of Continuous Casting .
2 Mizuno, M., Tsujita K., Kanazawa T., Minamimura Y., Iron & Steel Review October ’98, Sumitomo provides quality strip production process at Trico Steel
3 Flick A., CCC’96, Conroll® – The Tailor-made Answer for Thin Slab Casting and Direct Rolling
4 VDEh Plant Facts
5 Kropf A., CCR’04, SMART Segments / DynaGap – Technology That Makes You Money
6 Wahl H., Pennerstorfer P., Hauser K., Mörwald K., AISTech 2007, 3D-Sprays – Dynamic Secondary Cooling with Continuous Spray Width Adjustment
7 Wahl H., Federspiel C., Herzog K., CCR’04, Connect & Cast with VAI Casting Technology
8 Jungbauer A., Penn J., Wimmer F., S&I Kompendium – Das Referenzbuch für Sicherheit & Industrie 2007, Arbeitssicherheit durch Robotertechnik