Aciaria / Steelmaking
ISSN 1982-9345
43º Seminário de Aciaria – Internacional / 43rd Steelmaking Seminar – International

OPERATIONAL RESULTS OF THE WORLD'S MOST MODERN BOW TYPE CASTER WITH VERTICAL MOLD FOR THE PRODUCTION OF 355 MM THICK SLABS FOR DEMANDING QUALITY REQUIREMENTS[1]

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Abstract
In September 2011, the world's most modern bow type casters with vertical mold was commissioned at the steel plant No. 3 at voestalpine in Linz, Austria. The caster has a basic radius of 10 m and is designed for maximum slab thickness of 355 mm with a maximum width of 2,200 mm and straightening is carried out with a liquid core. The latest state-of-the-art technology, with adjustable spray nozzles (3D Sprays), EcoStar rollers and the latest generation of process automation models, such as Dynacs 3D, DynaPhase and DynaGap Soft Reduction®, have been implemented to achieve the highest quality of the produced slabs. Another highlight of this project is the installation of two LiquiRob industrial robot systems on the casting platform which increase the safety of the operating personnel dramatically. This paper gives an overview about the start up and highlights of these favourable caster concepts with selected operational results.
Key words: Thick slab; Plate; DynaGap Soft Reduction®; Dynacs 3D; DynaPhase; EcoStar rollers; LiquiRob.

RESULTADOS OPERACIONAIS DA MÁQUINA DE LINGOTAMENTO CONTÍNUO DO TIPO CURVO COM MOLDE VERTICAL MAIS MODERNA DO MUNDO PARA A PRODUÇÃO DE PLACAS ESPESSAS DE 355 mm PARA DEMANDA DE REQUISITOS DE QUALIDADE

Resumo
Em setembro de 2011, a Máquina de Lingotamento Contínuo de Placas do tipo curvo com molde vertical mais moderna do mundo foi colocada em funcionamento na Aciaria No. 3 na Voestalpine em Linz, Áustria. A máquina tem um raio base de 10 m e é concebida para uma espessura máxima de placa de 355 mm com uma largura máxima de 2.200 mm sendo seu endireitamento realizado com um núcleo líquido. As mais recentes tecnologias estado-da-arte, com bicos *spray* ajustáveis (*3D Sprays*®), rolos *EcoStar*® e a última geração de modelos de automação de processos, como *Dynacs 3D*®, *DynaPhase*® e *DynaGap Soft Reduction*®, foram implementadas para alcançar a mais alta qualidade das placas produzidas. Outro destaque deste projeto é a instalação, na plataforma de lingotamento, de dois sistemas de robôs industriais *LiquiRob*®, que aumentam drásticamente a segurança do pessoal de operação. Este artigo fornece uma visão geral sobre o *start-up* e destaques destes conceitos favoráveis de lingotamento com resultados operacionais selecionados.
Palavras-chave: Placa grossa; Chapa; *DynaGap Soft Reduction*®; *Dynacs 3D*®; *DynaPhase*®; *EcoStar rollers*®; *LiquiRob*®.

[1] *Technical contribution to the 43nd Steelmaking Seminar, May, 20th-23rd, 2012, Belo Horizonte, MG, Brazil.*
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ISSN 1982-9345

1 INTRODUCTION

The global market for flat products with highly sophisticated requirements like, ultra high strength or sour gas resistance has increased continuously in the past decades. To achieve high strength, together with a low content of alloying elements, a high deformation ratio of the slabs in the rolling mill is required. The thicker the final flat product, the thicker the slabs are required for reaching the correct deformation ratio. High strength combined with resistance against sour gas, especially for pipeline and offshore applications, needs perfect steel cleanliness and excellent internal quality of the cast slabs. At the new caster No. 7 at voestalpine Stahl Linz (Figure 1), latest state-of-the-art technology helps to ensure the above mentioned quality.

Production capacity:	1.4 Mtpy	Thicknesses:	225 / 285 / 355 mm
Heat size:	177 t	Width range:	740 – 2200 mm
Slab weight	Max. 40t	Cut length:	3.4 – 15 m
Machine radius:	10 m	Metallurgical length:	35.3 m
Max. casting speed:	2.0 m/min	Start-up:	September 20, 2011

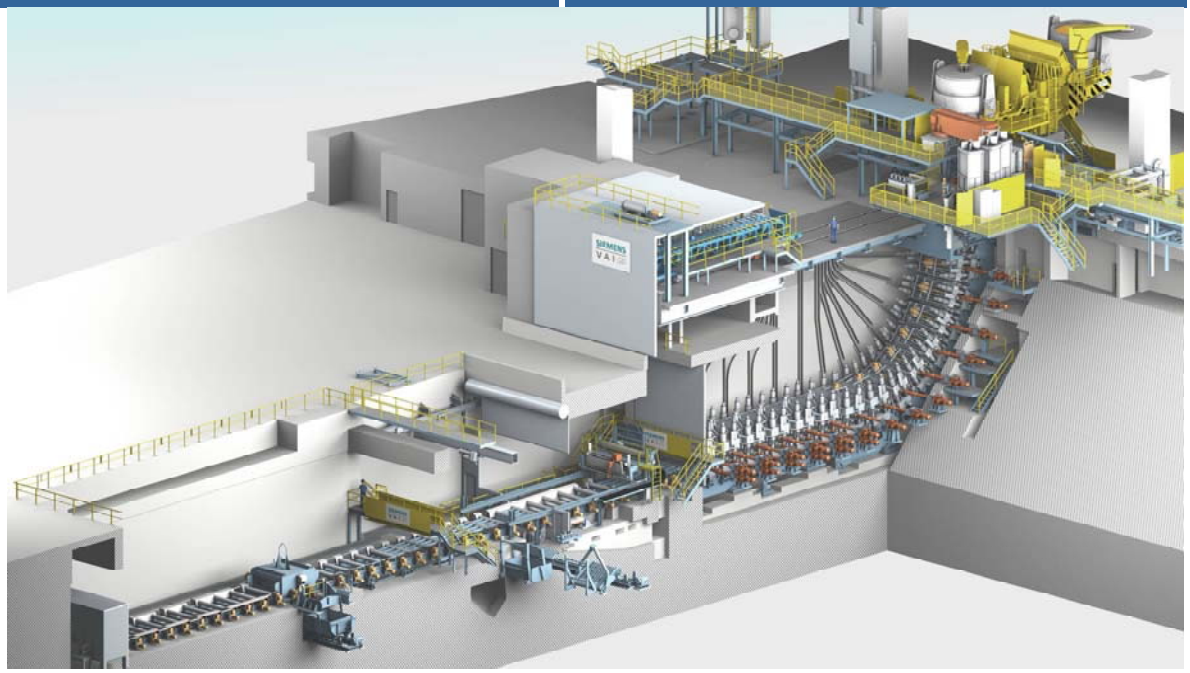

Figure 1. Layout of the new caster CC7 at voestalpine Stahl Linz.

The knowledge of the physical properties of different steel groups, from ultra low carbon to peritectic and up to ultra high carbon is extremely important for the optimal caster design, on which Siemens VAI has been and is continuously focused on. Thermal expansions, peritectic reactions, crack formation phenomena as well as the correct calculation of the solidification temperature from various steel grades have been subject of many investigations by Siemens VAI and their partners. During the casting process mechanical and thermal loads act on the solidifying strand shell which are resulting from:[1]

- Contraction and phase transformation;
- temperature gradients along the surface or across the shell;

- friction between strand and mold;
- bending and straightening;
- bulging;
- soft reduction etc.

According to their variety of chemical composition, carbon steels show a wide scatter in their properties during the continuous casting process. A comparison for example of the critical strain, nearby the solidification temperature reflects a significant decrease of the critical strain with higher carbon content, which directly results in an increase of crack sensitivity and furthermore into a higher downgrade ratio (Figure 2).[2]

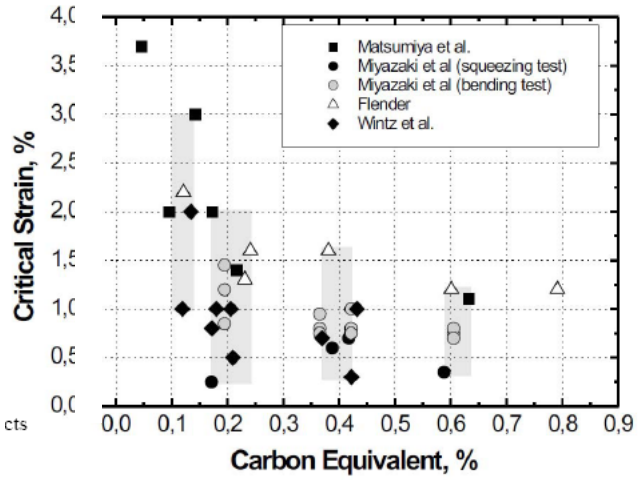

Figure 2. Experimental measured and calculated critical strain for crack formation.[2]

As we can see in Figure 2, only a simple variation of the carbon content results in a wide scatter of the properties of cast steel. In addition, for example with micro alloying elements the situation becomes much more complicated. All these phenomena had to be taken into account for the optimized design and settings of the voestalpine caster No. 7 for reaching a new quality benchmark in slab casting.

2 OPERATIONAL RESULTS

Historically only vertical casters were dedicated for the production of thick slabs with a high requirement on surface - and internal quality. With the development of bow type casters with straight mold and intelligent soft reduction solutions together with air – mist secondary cooling systems this dependence has reduced. For reaching the best slab quality Siemens VAI equipped the voestalpine caster No. 7 with adjustable spray nozzles (3D Sprays) and EcoStar rollers. In combination with the next generation of process automation models, such as Dynacs 3D, DynaPhase and DynaGap Soft Reduction® it is possible to reach the best surface and internal quality to fulfill the toughest quality standards for all kind of steel groups. Figure 3, the product mix cast since first heat, shows a wide range of different steel groups. Figure 4 shows the accumulated production since first heat on 20th of September 2011. Caster No. 7 has been operated, since 31st October, in 4 shifts. As of the 17th January 2012, approximately 240.000 tonnes of steel had been cast, which is approximately 17 % of the planned annual production.

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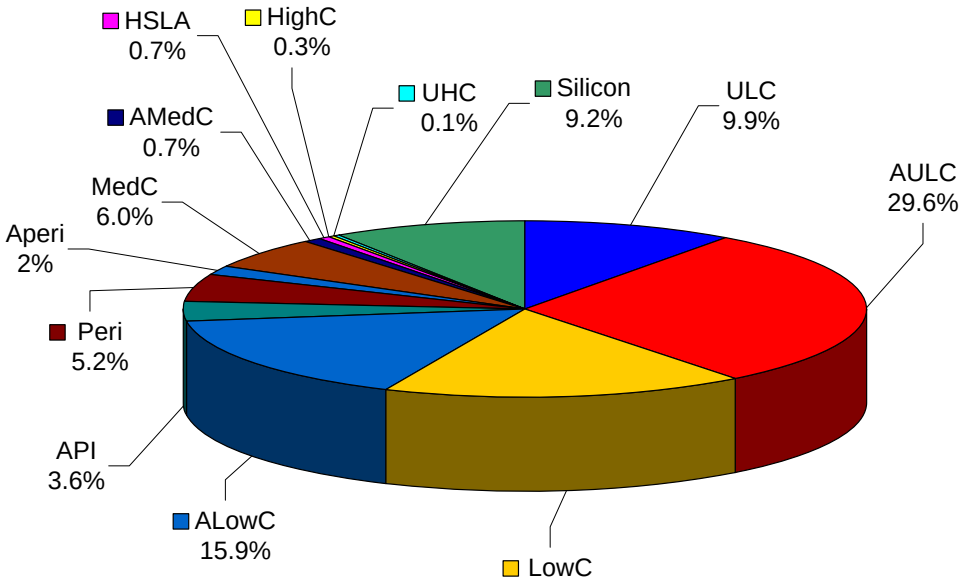


Figure 3. Product mix during the start up phase.

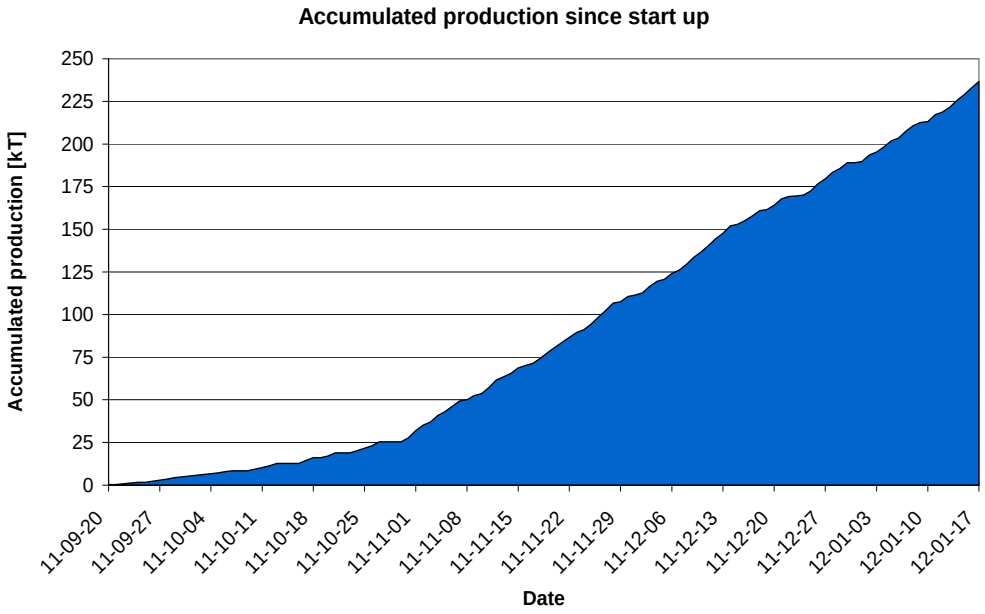


Figure 4. Accumulated production since first heat (119 days).

With the installed 3D Sprays linked with the new Dynacs 3D calculation model it is possible to adjust the correct water amount for each cooling zone over the whole slab width. Figure 5 shows the schematic layout of a Smart Segment, equipped with the adjustable 3D Sprays.

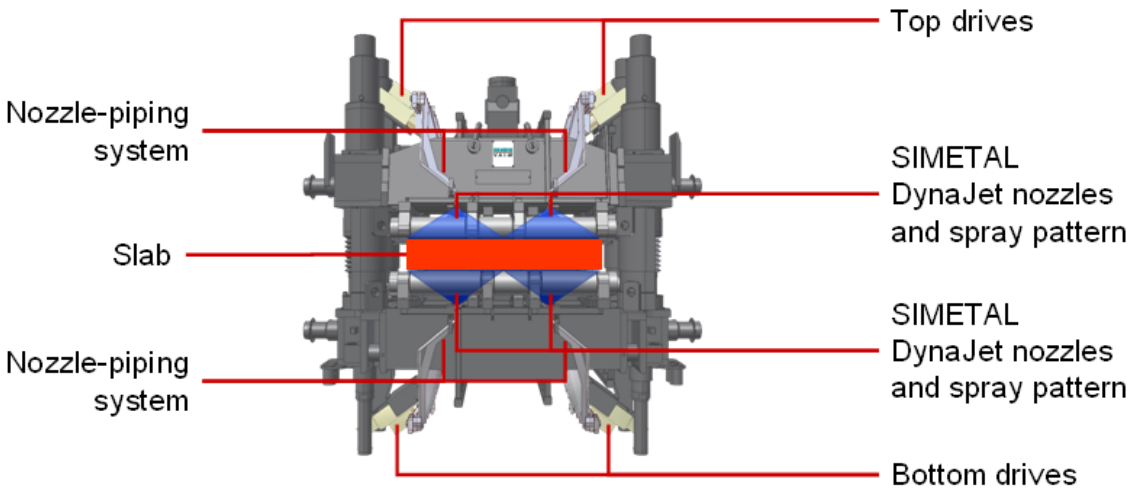
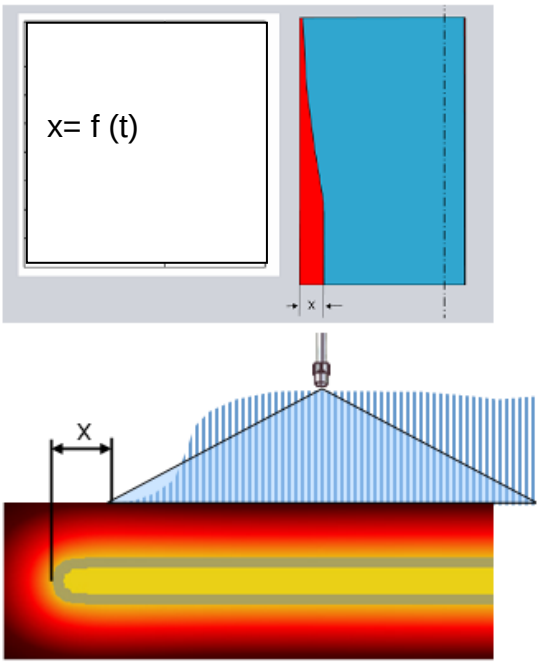


Figure 5. Schematic Layout of a Segment equipped with 3D – Sprays.

Control of the nozzle spray position and cooling intensity using 3D Sprays and Dynacs 3D for an optimized cooling strategy to prevent corner overcooling involves three control strategies for nozzle position:

- Distance of spray water to the slab corner based on the position in the machine;
- distance of spray water to the slab corner is based on the age of the strand at the corresponding position;
- distance of spray water to the slab corner is based on the calculated shell thickness (solidus temperature).

This system gives the possibility to avoid low ductility or brittle temperature zones at the slab corners. Especially for slab thicknesses over 250 mm, which the machine CC7 is able to cast, the avoidance of critical temperature ranges is a big issue. Figure 6 gives an example of the 3D nozzle position whereas in this case the nozzle position is based on the age of the strand.



Top view

Cross view

Figure 6. Postion of 3D Sprays related to the strand age.

Due to this flexible adjustment of the spray nozzles it is possible to optimize the surface temperature profile according to the slab width along the relevant cooling zones. Figure 7 shows an example of the calculated surface temperature profile at the (a) entry and (b) exit of the straightening area.

a)

b)

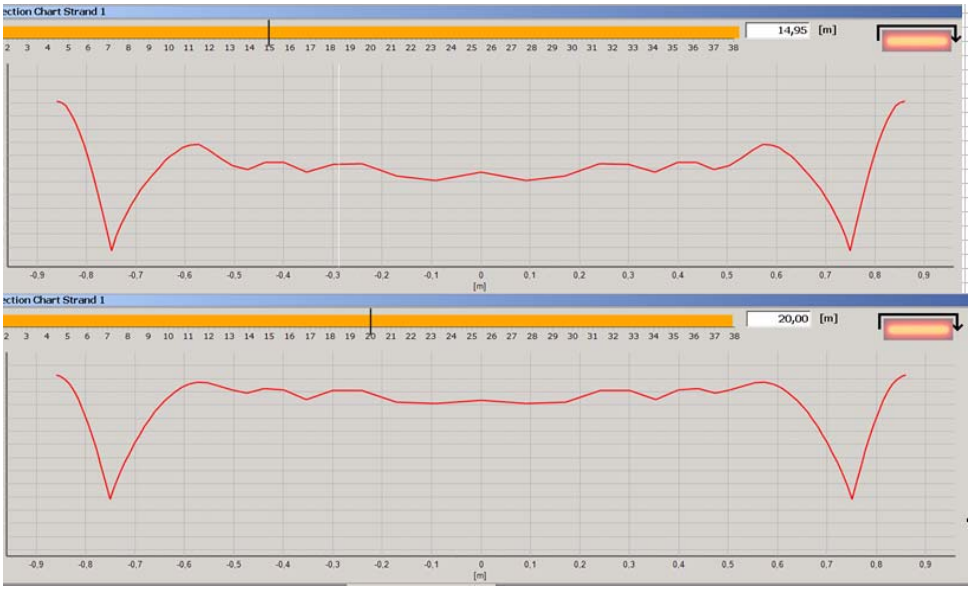


Figure 7. Surface temperature profile over the width (a) entry straightening area; and (b) exit straightening area.

Furthermore the adjustable 3D Spray system creates a more uniform solidification profile. The more uniform the solidification front, the higher efficiency can be reached of the Dynamic Soft Reduction®. An example of a simulated optimized solidification front can be seen in Figure 8. Due to Siemens VAI´s simulation tools it is possible to prepare offline the finest caster practice to achieve the perfect product quality.

(a)

(b)

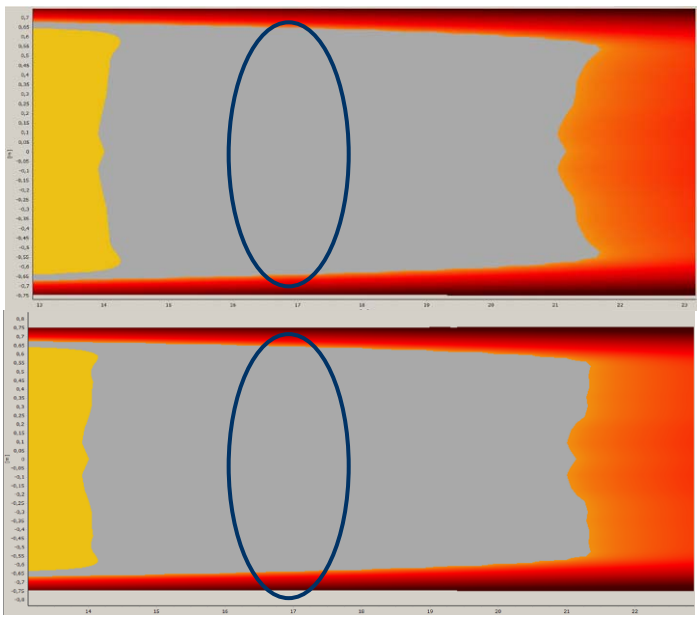


Figure 8. More uniform solidification front due to optimized spray pattern and nozzle position (a) before optimization; and (b) after optimization.

In addition to a uniform solidification front the correct knowledge of solidification parameters, like the solidification temperature, heat conductivity, as far as peritectic reactions are necessary. For this reason several reference steel grades are pre-calculated with the new DynaPhase model, that ensures for a wide range of different steel chemistries a very exact prediction of those parameters. Based on this knowledge Dynacs3D the accurate calculation of the final solidification point and the area of the mushy zone is ensured. As a result of these high accurate calculation models it was possible to reach the highest surface quality and internal quality levels such as centre segregation, which can be seen on a macro etched sample of a ultra high carbon steel with a carbon content of 0.75 wt - % (Figure 9).

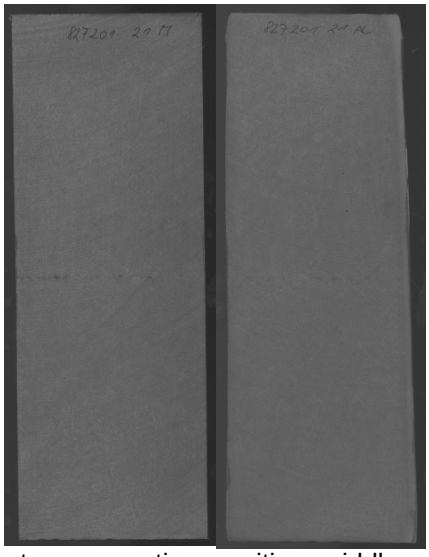


Figure 9. Macro etches centre segregation; position: middle; material: C75, C = 0.75%C.

The macro etches of an Alloyed Medium Carbon steel (Figure 10), give another example of the high quality centre segregation level.

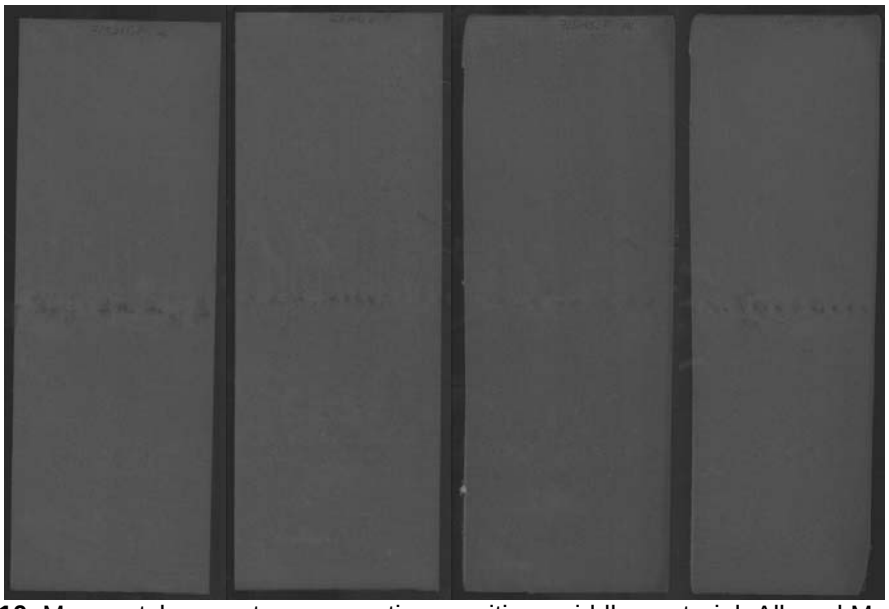


Figure 10. Macro etches centre segregation; position: middle; material: Alloyed Medium C.

Due to the wide range of steel chemistries for which the casting machine CC7 is used, the behaviour during the whole solidification and cooling down range has to be

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known. In this case the new DynaPhase model includes also an extended database, which is able to predict the peritectic range, especially for new grades with high Al, Si and Mn content.

Finally the two equipped LiquiRobs have to be mentioned. For the first time in a steelplant, two LiquiRob industrial robot systems have been installed on a slab caster. The LiquiRobs have been installed in front of and behind the ladle turret, one in the ladle-positioning-area and the other in the ladle/tundish area on the casting platform. The LiquiRobs ensure the highest possible working place safety combined with an increase of reproducibility. The two LiquiRob's at the CC7 take over following operations:

- Ladle area:
  - media/electric quick coupling;
  - connection shroud clamping and slide gate cylinder;
  - unlocking of ladle bolt.
- Tundish area:
  - temperature/O_2/H_2 measurement & sampling ;
  - tundish powder dosing;
  - shroud handling;
  - ladle lancing.

Figure 11 shows the sample handling (a) and the ladle shroud manipulation (b) of the LiquiRob #2 installed in front of the ladle turret.

(a) (b)

Figure 11. (a) sample handling; and (b) laddle shroud manipulation with LiquiRob.

In the Figure 12 LiquiRob #1 is attaching the ladle shroud handling device (LSH) at the first heat. Since the first heat both installed LiquiRobs are in operation.

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Figure 12. LiquiRob attaches the ladle shroud handling device on the first heat.

3 CONCLUSIONS

The success of the recent thick slab caster project at voestalpine Stahl Linz is the logical result of continuous developments at Siemens VAI together with the excellent cooperation with voestalpine Stahl engineers.
The installation of the slab caster No. 7 at voestalpine Stahl is setting a new benchmark in casting of high quality steels by increased operator safety.

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