SETTING NEW STANDARDS IN OPERATOR SAFETY AND PRODUCT QUALITY – 1 STRAND SLAB CASTER CC 7 AT VOESTALPINE LINZ[1]

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Abstract
In September 2011, one of the world's most modern slab casters was commissioned at voestalpine Stahl GmbH steel plant LD Nr. 3 in Linz, Austria. The caster covers a wide range of thicknesses from 225 mm to 355 mm and widths from 740 mm to 2200 mm and is equipped with the latest state-of-the-art technology, e.g. Smart bender, width adjustable spray nozzles (3D Sprays) and the latest generation of process automation models, such as the further advanced secondary cooling system Dynacs 3D and DynaGap Soft Reduction®. These technological features have been implemented to achieve the highest quality slabs. Unique and the first time ever installed in a steel plant is the operation of two LiquiRob robots which completes all the dangerous work activities automatically and allows monitoring of casting process from the safety of the control room. An overview about this unique safety operation concept and selected operational results of this most modern casting machine are highlighted.
Key words: Thick slab; LiquiRob; 3D spray system; DynaGap Soft Reduction®; Safety.

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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:	1.2 Mtpy	Thicknesses:	225 mm / 285 mm / 355 mm
Heat size:	177 t	Width range:	740 mm – 2,200 mm
Slab weight	max. 40 t	Cut length:	3.4 m – 15 m
Machine radius:	10 m	Metallurgical length:	35.3 m
Max. casting speed:	2.0 m/min	Start-up:	September 20, 2011

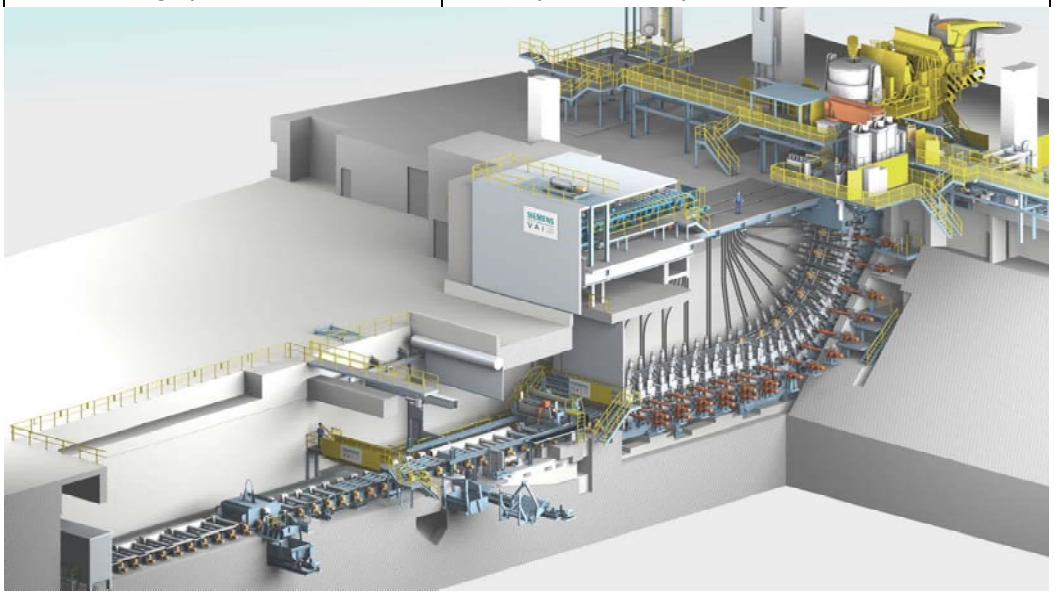

Figure 1. Layout of the new caster CC7 at voestalpine Stahl Linz.

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.

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.
A wide range of different steel groups are cast since first heat as shown in Figure 2.

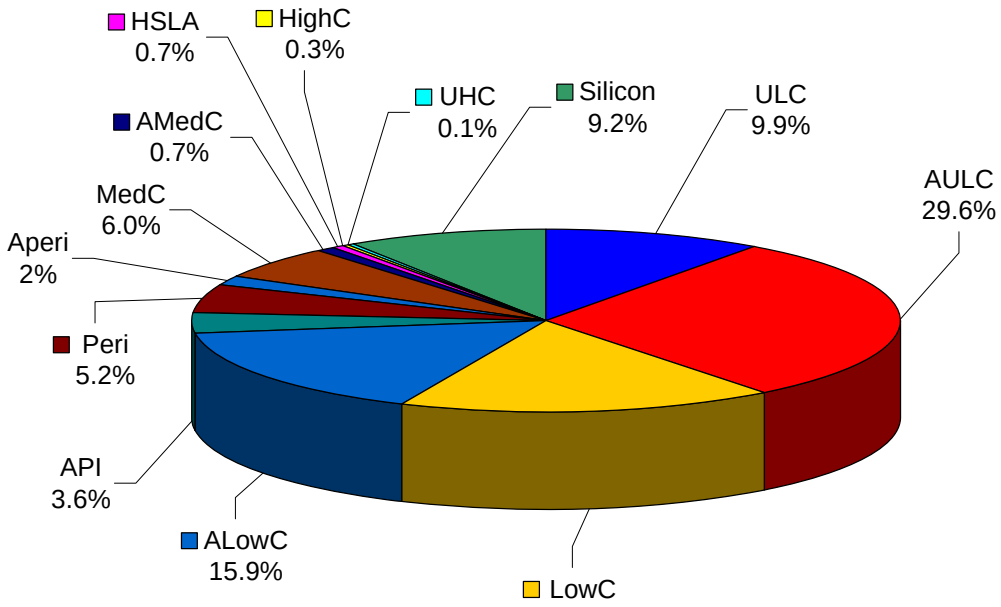

Figure 2. Product mix during the start up phase.

Figure 3 shows the accumulated production since first heat on 20th of September 2011 and shortly after first heat it was clear that the caster exceeds all expectations as the first heats have been marketable. From October 31st 2011 the caster No. 7 has been operated in 4 shifts under full capacity. In September 2012 only 11 months later the record value of the first million tonnes of steel was reached as 5,955 heats, 38,799 slabs were cast with an average slab weight of 25,9 t and 10 m slab length. With this performance it was possible to produce an aligned slab bridge which spans the distance from Vienna to Munich.

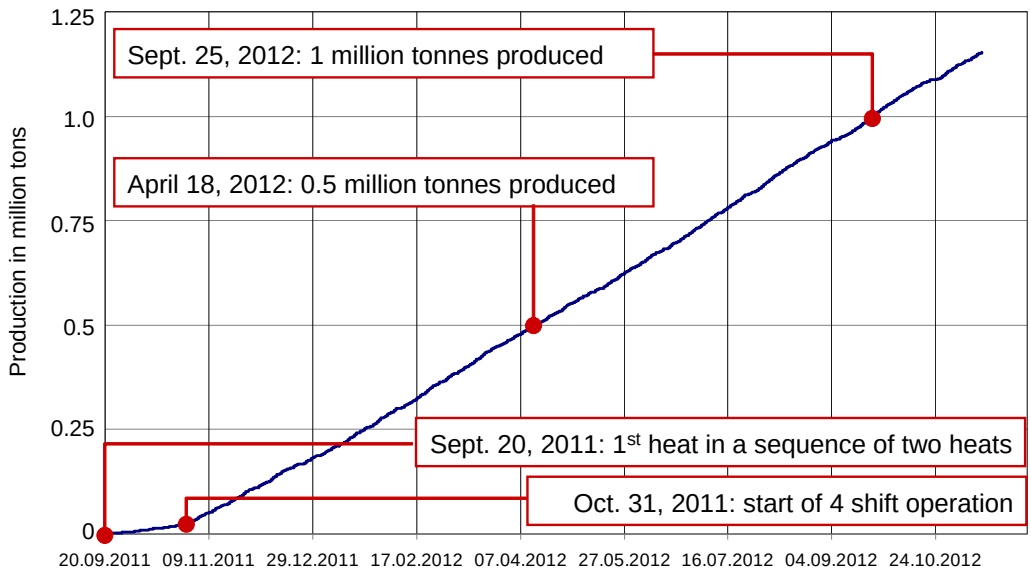

Figure 3. Accumulated productions since first heat.

3 DESIGN FEATURES AND TECHNOLOGICAL PACKAGES

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 4 shows the schematic layout of a Smart Segment, equipped with the adjustable 3D Sprays.[3]

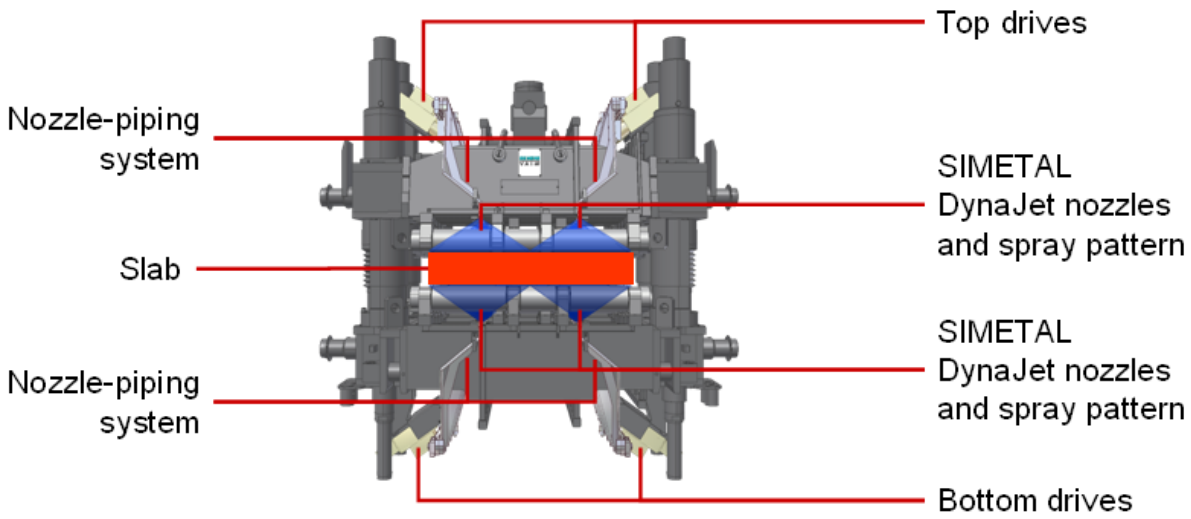

Figure 4. Schematic layout of a segment equipped with 3D Sprays.

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.
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.[3]
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®.[4]
An example of a simulated optimized solidification front can be seen in Figure 5.
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)

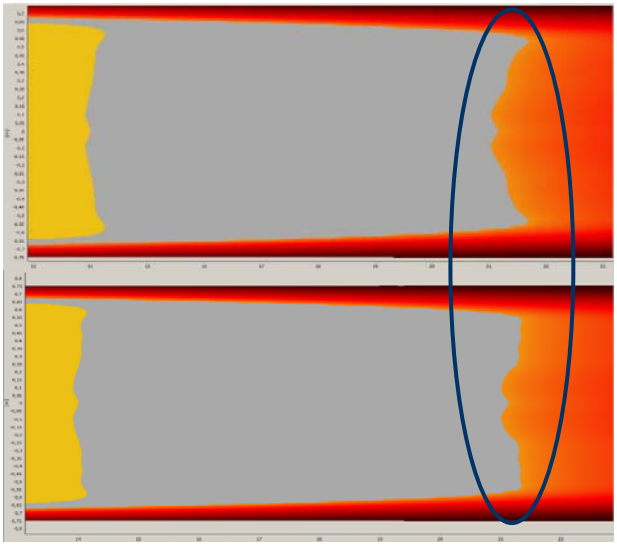

Figure 5. More uniform solidification front due to optimized spray pattern and nozzle position (a) before optimization; and (b) after optimization.

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, with Dynacs 3D 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 ultra high carbon steel with a carbon content of 0.75 wt - % (Figure 6).

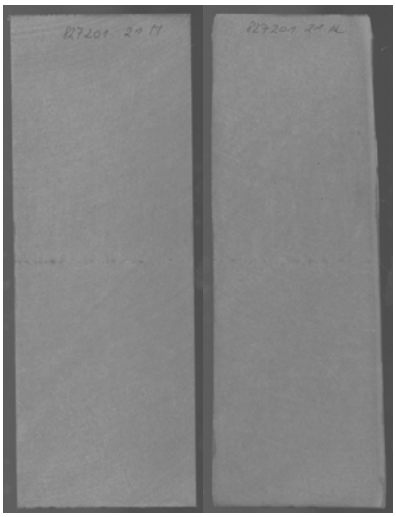

Figure 6. Macro etches centre segregation; position: middle; material: C75, C = 0.75%C.

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

4 LIQUIROB - FULL FLEDGED ROBOTIC APPLICATIONS FOR STEEL PLANTS

The SIMETAL LiquiRob is an impressive example of modern applied Mechatronics in the harsh environment of steel industry. This highly flexible robotic system is capable of performing a wide variety of dangerous and systematic tasks. At voestalpine CC7 two LiquiRob Systems are installed with the target to set a higher safety standard for operation people and to increase the process stability and reproducibility.[(5)]
One LiquiRob is installed at the ladle area and connects and removes the equipment attached to the ladle, therefore it is no longer necessary for the operation people to work below the hot ladle full of liquid steel.
The second LiquiRob is installed at the tundish area and performs tasks like taking steel samples or open's a ladle by oxygen lancing if the ladle is "frozen". The LiquiRob system is fully integrated in the plant automation and therefore a fully automatic operation of the LiquiRob's is performed. Additionally the operation people have the freedom to interact with the system, from the safety of the control room and can feed so called working queues and the LiquiRob executes each operation task after each other.
During the first months of operation, taken records showed an impressive value as the LiquiRob executed about 1,000 times steel probes from the tundish or executed temperature measurements successfully and proved the stability as well as the high availability of the LiquiRob system.
Also in the ladle area an optical measurement system in combination with the LiquiRob was installed the first time in the harsh environment in a steel plant. The optical measurement system serves for the identification of the targets which are the basis for connection and removing of the required equipment at the ladle.
With the installation of these two LiquiRob systems Siemens VAI demonstrates his leadership in robotic applications in steel plants and it shows the future direction of plant operation with a maximum on personal and operational safety.
Below is a summary of the tasks performed by both LiquiRob systems.

LiquiRob in ladle area:

- connect shroud clamping and slide gate cylinder (LSH);
- connect multi-coupling system for media like argon / electric;
- unlock of ladle bolt.

LiquiRob in tundish area:

- temperature/oxygen/hydrogen measurement;
- taking steel samples;
- shroud handling;
- tundish powder dosing;
- ladle oxygen lancing.

Figure 7. Sample handling with LiquiRob.

5 STATE OF THE ART CONCERNING SAFETY

Another important issue in plant design is the “Conformity with Regulations and State of the Art concerning Safety” which becomes more important and is nowadays mandatory for new installations in European steel plants.
The European standard EN 14753 (safety requirements for machinery and equipment for continuous casting of steel) for continuous casting machines have been applied at the CC 7 at voestalpine in Linz.
Extensive analysis and several safety documents like:

- risk analysis, which dictates technical and organisational safety measures;
- safety identification plan, showing dangerous areas, escape routes, safety signs and additionally safety information;
- operational safety instructions have been worked out and were the basis for safety equipments installed in mechanics and automation systems.

Another feature of SVAI safety system comprises the design of the mold cooling system to fulfill performance level PL e/category 4. Instrumentation and sensors according to required performance level where selected and the design of hydraulic controls is according to required performance level.
The control system for safety related parts fulfils the requirements of the EN ISO 13849-1, safety PLC’s for critical functions are installed and a selection of safety-related parts of control systems suit the safety functions and the necessary level of

safety, e.g. sensors, logic units, power control elements as well as drives and actuators are installed.
Collision protection functions against interferences for specific equipment of plant (e.g. ladle turret / tundish car) are forseen.
All these measures are based on legal and normative basics like machinery directive 2006/42/EG, standards like EN ISO 12100:2010 incl. safety of machinery comprising general principles for design – risk assessment and risk reduction as well as the EN 14753:2007 comprising safety of machinery - safety requirements for machinery and equipment for continuous casting of steel.

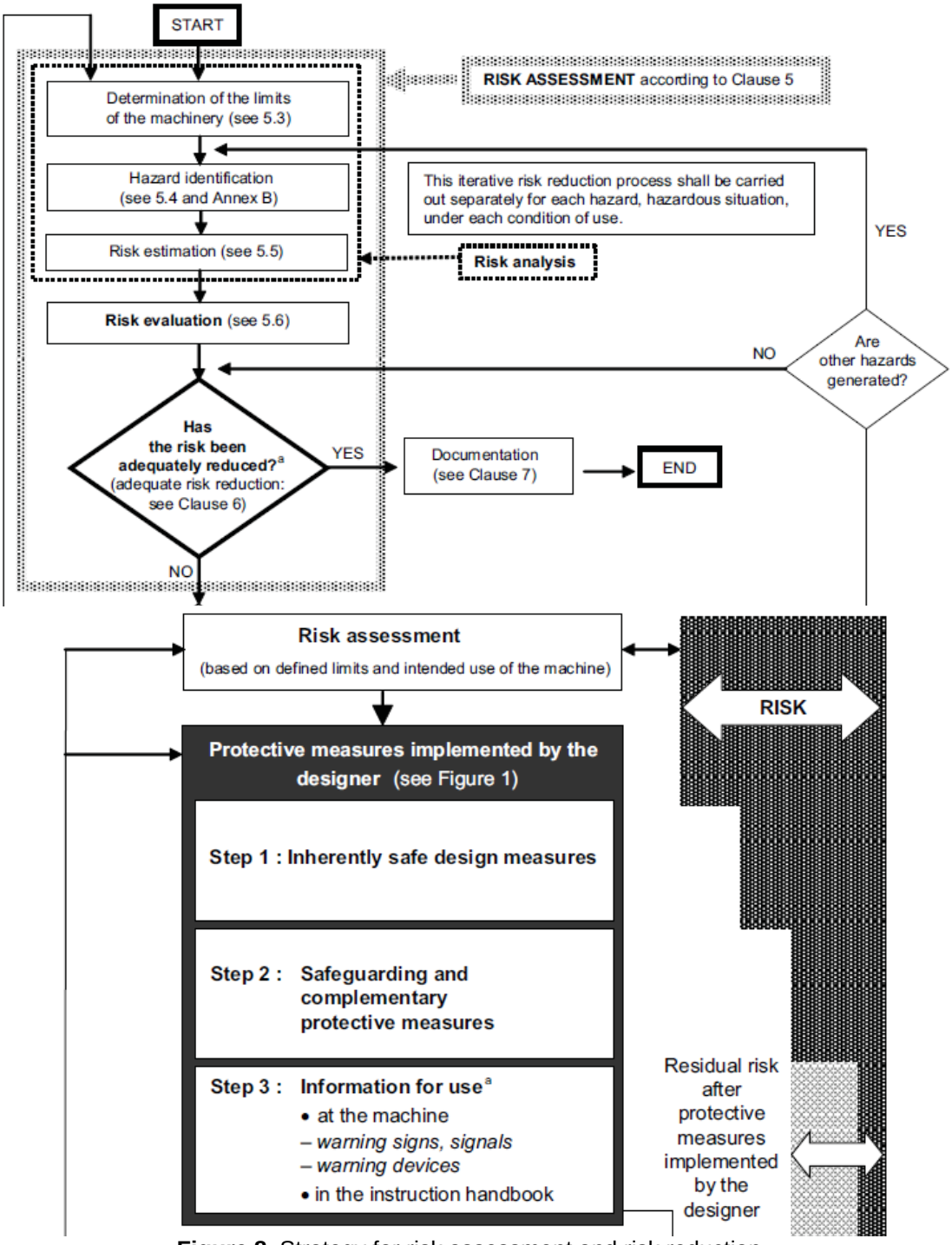

Figure 8. Strategy for risk assessment and risk reduction.

6 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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