CAST FLOOR ROBOTICS – CONCEPT AND TEST RESULTS[1]

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Abstract

In the last years, the worldwide safety standards in continuous casting have improved, but there is still imminent danger on the casting platform due to the fact that large volumes of liquid steel are handled above the casting floor level where operators have to fulfil their work. In the meantime, robots and their accessories have been further developed and have begun to conquer steel plants by fulfilling many tasks. In addition to numerous simulations and feasibility studies, VAI began excessive laboratory tests to prove the simulations under real conditions. Building up a casting platform with wooden mock-ups of the mold, tundish and ladle provides the perfect surrounding conditions for testing. After arranging the magazines and tool holders, the gradual development of all processes began. SIEMENS-VAI started a development for full automatic operation of all activities on the cast floor of continuous casting machines. A full size test robot was installed in a laboratory with on board position detection and all necessary tools. Based on a mockup of ladle, tundish and mould specific solutions for allowing full automatic operation were engineered, manufactured and tested. The results of the studies, tests and realisations are presented and discussed.

Key words: Caster safety; Robotics; Continuous casting.

CAST FLOOR ROBOTICS – CONCEITO E RESULTADOS DOS TESTES

Resumo

A SIEMENS-VAI iniciou o desenvolvimento da completa operação automática de todas as atividades no chão da máquina de lingotamento. Um robô de testes em tamanho real foi instalado em um laboratório com detecção de posição e ferramentas necessárias. Baseado em um modelo de panela, distribuidores e moldes, soluções específicas para permitir operação totalmente automatizada foram projetadas, construídas e testadas. Os resultados dos estudos, testes e operações serão apresentados e discutidos neste trabalho. Em adição às numerosas simulações e estudos de viabilidade, a VAI iniciou excessivos testes de laboratório para provar as simulações em condições reais. Construção da plataforma da maquina de lingotamento em madeira para suportar os moldes, distribuidores e a panela as condições de testes foram atingidas. Depois de arranjar os magazines e portadores de ferramentas o desenvolvimento gradual do processo se iniciou. Nos últimos anos, os padrões mundiais de segurança em Lingotamento Contínuo evoluíram, mas ainda existe risco iminente na plataforma do lingotamento, uma vez que grandes volumes de aço líquido são manuseados acima do nível em que os operadores da máquina realizam seu trabalho. Enquanto isso, robôs e seus acessórios sofreram evolução significativa e já começaram a conquistar as usinas siderúrgicas realizando diversas tarefas.

Palavras-chave: Segurança em lingotamento; Robótica; Lingotamento contínuo

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INTRODUCTION

In the last years, the worldwide safety standards in continuous casting have improved, but there is still imminent danger on the casting platform due to the fact that large volumes of liquid steel are handled above the casting floor level where operators have to fulfil their work. Even in the 1970's, the so-called "no man casting" was promoted. However, in those days the technology not advanced enough to perform it in a reasonable way.

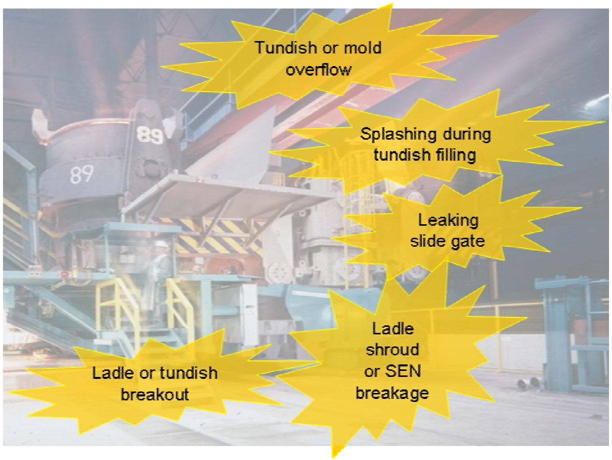

Figure 1 Dangers on casting platform

In the meantime, robots and their accessories have been further developed and have begun to conquer steel plants by fulfilling many tasks.
Following this trend and consequently taking it a step further, Siemens VAI decided to develop the technology for fully automatic casting floor operation - from the beginning to the end of casting.
This kind of operation can be carried out using two to four robots that are located on the casting floor in specific areas, forming so-called "operation cells". The exact positioning very much depends on the individual caster layout and it may be necessary to place the robots on a lever to make them moveable and thereby increase their operation range. Figure 2 shows such an arrangement as an outcome of a study that was performed for a North American caster.

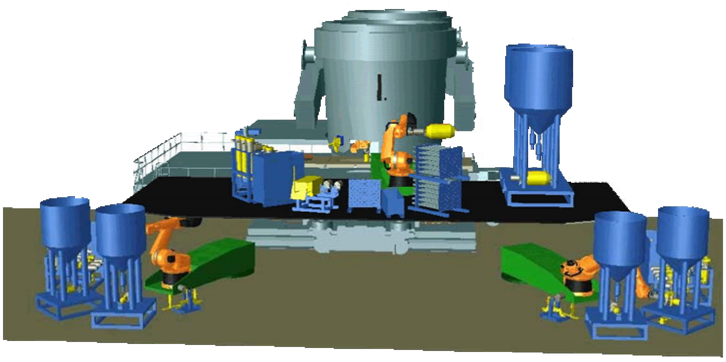

Figure 2 Arrangement of robotic system

LABORATORY AND FUNCTIONS

In addition to numerous simulations and feasibility studies, Siemens VAI began excessive laboratory tests to prove the simulations under real conditions. Building up a casting platform with wooden mock-ups of the mold, tundish and ladle provides the perfect surrounding conditions for testing. After arranging the magazines and tool holders, the gradual development of all processes began.

Figure 3 Laboratory test arrangement

The Working Areas

The operational area generally has three divisions. In the ladle load position, operations like media and signal connections are undertaken. On some casters the ladle slide gate cylinder is connected in this position.
In the casting area at the tundish, LiquiRob handles the ladle shroud manipulations, temperature measurements and probe manipulations. The tundish powder application is also a job for LiquiRob.
In the mold area, all the dangerous activities, which are typically done by operators, form the tasks for LiquiRob. Casting powder application, SEN exchange activities, slag removal and also the placing of the separator plates is included.
Some functions are very challenging due to the fact that the operated objects do not remain in fixed positions but are movable. A position detection system is then required.

Position Detection

One of the major challenges for robotics in continuous casting machines is the fact that some objects do not have fixed positions. The equipment which is mounted on ladles and tundishes is movable and is therefore never in exactly the same place. On the ladles, the couplings for media and signals as well as the ladle slide gate cylinder are affected. On tundishes the exact position is important for the exchange of the sub entry nozzle.
Usually position detection systems approach the problem either with laser detection or with camera systems. Several tests of laser systems in steel plants have shown that the laser beam is sensitive to dust or other particles in the air which disturb the exact and reliable operation. Camera systems do not display detected problems due to diffusion in the air.

After several analyses, two systems were tested in detail and the better system then had to undergo a detailed test series.
In addition to reliability, one of the main aspects is the quick target recognition. During the feasibility studies and the time analyses, Siemens VAI defined a maximum detection time of 4 seconds. During the tests the system which is in use on LiquiRob easily achieved the required detection time.
In the most useful system configuration, the two cameras, which allow for stereo position detection, are mounted directly on the robot head. Due to this mounting position, the freedom of the system is drastically increased compared to stationary systems. After the LiquiRob head is moved to the detection position, it has a perfect view of the detection plate.

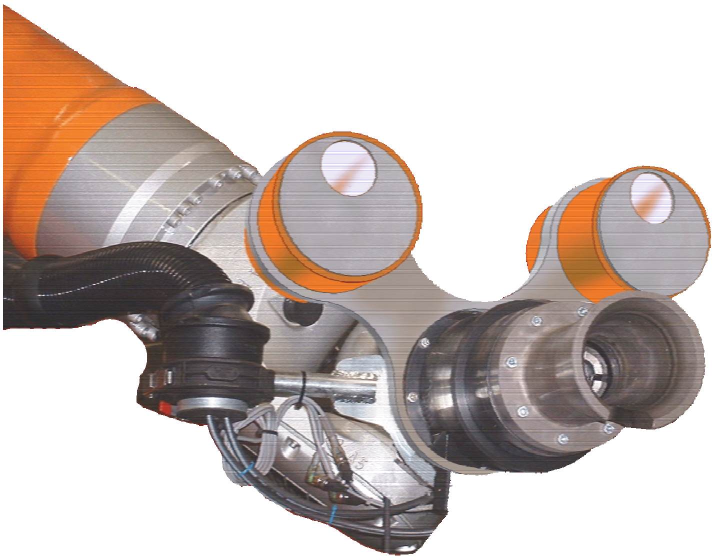

Figure 4 Position detection

With a reference plate mounted on the ladle or tundish, the system analyses position deviations in all three axial directions as well as the rotation of the target objects. The deviation parameters are then automatically transferred to the robot control and are there used as offset factors. Since the position detection system is one of the key elements, this part was checked very carefully.
In regard to light sensitivity, an operation range from 5 to 200 lux is possible. This is sufficient for the operation in steel plants. Also the robustness of the detection plate had to be extensively tested. A plate was mounted on a ladle which had been in operation in a steel plant. After six months of operation, the corroded and dirty plate was dismounted and was then used in the laboratory for the ongoing tests without any problems. Further tests were made with varying light conditions, and with smoke and dust on the detection plates. One test series investigated partly covered detection plates and the recognition system performed with satisfying results.
Out of currently more than 300 tests, all were successful.


Figure 5 Position detection tests under steel plant conditions

To ensure safe operation, the cameras are covered by protective housing. This protects the precision cameras from mechanical strokes as well as dust, liquids, steam or heat. After maintenance activities on the cameras or the housing, LiquiRob starts an automatic calibration cycle with a reference plate. No further complicated maintenance or operator activity is required.
The position detection package is optional and installed only if required by one of the functions. Due to the modularized approach that Siemens VAI already applies in several successful technological packages, it is now possible to configure a robotic solution according to customer requirements. From the simple probe manipulations to more demanding functions like ladle shroud operations - all possible combinations can be configured and adapted.

The Functions

In the ladle load position, LiquiRob begins with the connection of media and signals. This work is done utilizing the newly developed Siemens VAI multi-coupling.

Place Multi-coupling

Very often, several media connections like argon or hydraulic oil have to be linked to the ladle. Electric signal connections are also needed, e.g. for slag detection. The quick coupling system is set after detection of the ladle position by the position detection system. After the coupling has been brought in position by LiquiRob, the pneumatic clamping is automatically locked and the LiquiRob tool grip can release the coupling.
During the theoretical analyses and FMEA analyses, the need for backup systems was considered. Simple hand manipulators are therefore installed to enable an uninterrupted casting process in case of a robot failure.

Mounting of Ladle Slide Gate Cylinder

On some casters the operators have to do very dangerous work – for example the connection of the ladle slide gate cylinder. Adapting the cylinder with a robot grip enables LiquiRob to take over the work in this dangerous area. To perform the connection, the use of the position detection system is obligatory to detect the exact position of the cylinder connection point.

Moving to the tundish area in the casting position, a lot of work awaits LiquiRob.
Originally, when a new ladle was turned to its casting position, the ladle shroud had to be connected. This work was typically done by hand or by automatic ladle shroud manipulators with all of the well-known problems of imperfect connections, adjustment work for manipulator force and side forces during slide gate movements.
Siemens VAI tested an original slide gate from a North American steel producer and the slide gate LTC from Vesuvius in the laboratory. After handing over the shroud to the slide gate mechanism, LiquiRob is free for other activities on the ladle operator platform.
This is the main feature that distinguishes the implementation of robotic solutions from the use of manipulators. Up to now, the typical approach of casting floor automation was the arrangement of several manipulators from different machine building companies. The entire ladle operator platform was full of special machines with limited operation ranges that had to be coordinated. In between these machines, the operators still had to work with all the known dangers. LiquiRob now offers the possibility to free the operators completely of their dangerous work. When comparing the costs of many different manipulators with the purchase of one LiquiRob system, LiquiRob clearly offers additional financial advantages.

Ladle Shroud Cleaning

LiquiRob can also automate the ladle shroud cleaning. After removing the shroud from the ladle, it is brought to the oxygen shower. Optionally, an intermediate stop at a video camera can be made to give the operator the possibility to decide on shroud cleaning or replacement. Once the cleaning process has been completed, LiquiRob places the shroud at the new ladle.

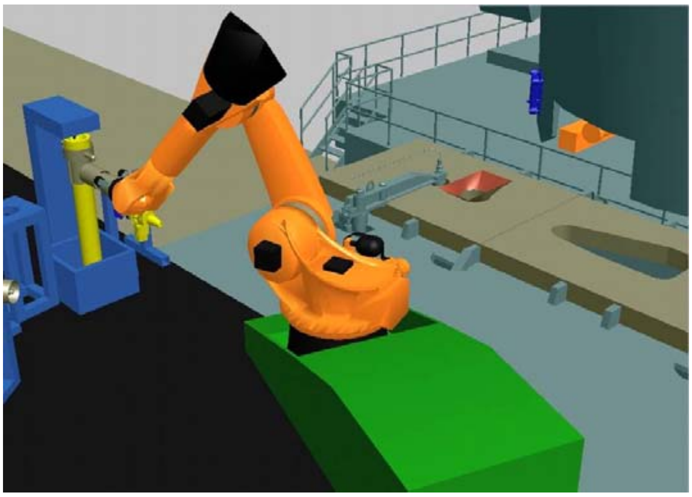

Figure 6 Ladle shroud cleaning

Oxygen Lancing of Ladles

One of the most dangerous activities for operators is the oxygen lancing of ladles that will not open. The engineering of the oxygen lance is in progress and tests in the laboratory will soon start.
The main sequence of each operation is similar:

- Take the tool from the tool holder

- Pick up additional parts (optional)
- Execute the job
- Drop used parts (optional)
- Return the tool to the tool holder

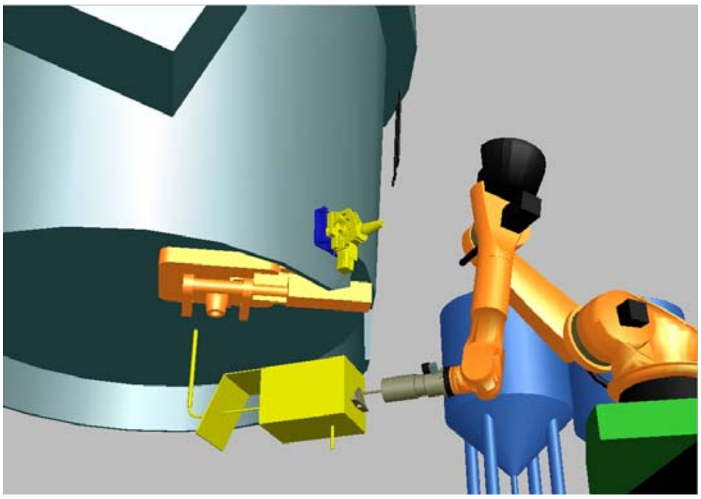

Figure 7 Opening of ladle by oxygen lance

Applying tundish powder

Applying the tundish powder with a robot automatically offers the possibility of total quality control. The powder, stored in one or more storage hoppers is to be filled into the LiquiRob-tool - the shovel. The integrated weighing system provides supervision by analyzing the status of the hopper and the shovel. The real amount of powder carried into the tundish is registered for further quality control analyzes.

Figure 7 Filling up the shovel

The movement of the powder distribution by the robot can be taught-in according to the tundish configuration. The powder can be filled into open tundishes as well as directly into the filling holes of covered tundishes. The shovel design, together with a defined shovel movement and rotation, grants an exact powder distribution


Figure 8 Placing of tundish powder

Tundish Temperature Measuring

As an operator would do, LiquiRob takes the temperature measurement tool from the holder, picks up a probe from the magazine and then moves towards the tundish. After the measurement is completed, the used probe is placed into the disposal box. The magazine can be refilled by operators during the normal operation period without having to enter the fenced operation area of LiquiRob.


Figure 9 Funnel magazine

The funnel at the magazine ensures a safe probe pickup.

Sampling from Tundish

For sampling from the tundish, the same magazine that is used for tundish temperature measuring is used. The timing for the start of a new sampling sequence is handled in the expert system, which is part of the motion controller. The coordination of the activity sequences is handled from the expert controller but the operator still has the possibility to activate additional measurements, samplings or other activities.

Figure 10. Sampling from tundish

To extend the operation range of LiquiRob, a turning arm is provided. Thus the robot can reach all magazines behind it as well as the most distant tundish powder hole or the ladle slide gate nozzle for shroud connections or oxygen lancing.
In the ladle area, the danger of splashes from liquid steel is rather high, even for LiquiRob. Thus the robot has to wear a protection coat just as an operator does. The coat also protects the robot from dust and heat. The robot spends the rest period in protective housing in the ladle load position.
The only dangerous area that remains for operators is the mold area. Since the final objective is a complete robotic solution for the casting floor from the start until the end of casting, all casting floor operations have to be automated.

Applying casting powder

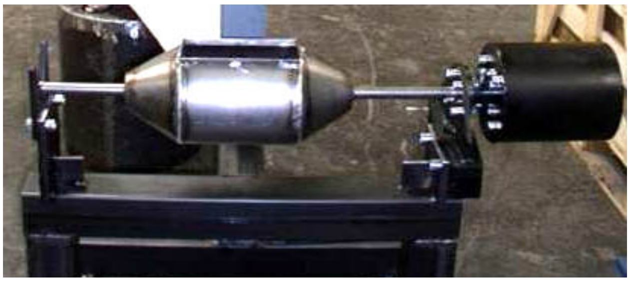

Figure 11 Place casting powder

For the mold powder application, many interesting and more or less complicated manipulators have been engineered. The simplest solution is still to apply the powder using a shovel. The powder is distributed by LiquiRob on the left and right side of the sub-entry nozzle. As in the case of the tundish powder, here there is also the possibility of total quality control.

Slag Removal from Mold

For almost every activity, a robot is used to open the doors. With the design of the right tools, the activity list of LiquiRob can be easily extended. The slag removal e.g. can be conducted with a specially designed shovel. The slag is picked up on each side of the sub entry nozzle and disposed of in a waste container.

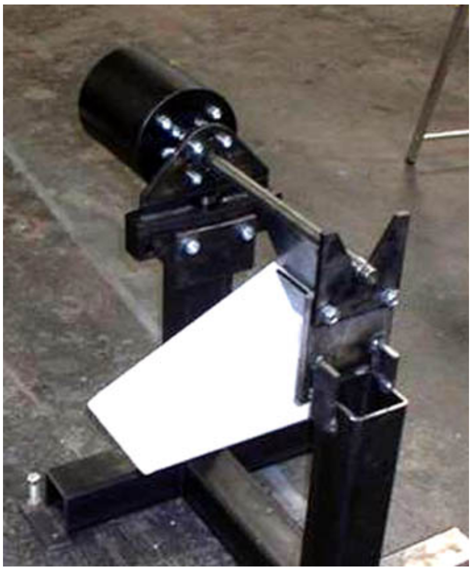

Figure 12 Slag removal from mold

Placing the separator plate

The separator plate can also be set by LiquiRob. The newly developed mechanism of the plate setting tool works with springs and was successfully tested in the laboratory.

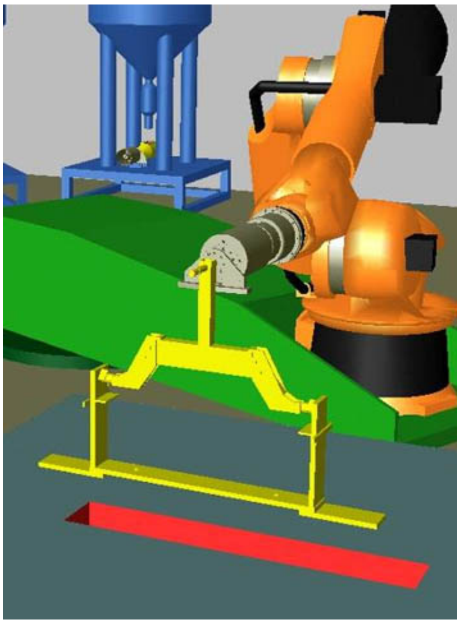

Figure 13 Place separator plate

Since Siemens VAI's objective is a safe and smooth implementation of the LiquiRob technology package, all functions were tested extensively until they worked satisfyingly. The test and development sequence at Siemens VAI's laboratory will soon be finished with the final successful testing of oxygen lancing. Later, the laboratory shall be available for customers who prefer a complete simulation of their casting floor under real conditions before the implantation in their plant.

CONCLUSION

The 3D-CAD layout studies, robot simulations and laboratory tests showed that all elements of a fully automatic casting floor operation using a limited number of robots are feasible. Furthermore it was discovered that an absolute key element of the whole technology is the position detection sensor.
The twin-video camera sensor mounted onto the robot arm proved its superiority compared to other sensor systems due to its

- measuring accuracy due to the system itself and its proximity to the measuring plate
- measuring speed with detection times below 4 seconds
- flexibility due to the moving possibility
- simple handling with regards to sensor exchange and calibration features
- sturdiness with regards to disturbances (light, dust, angle, interfering objects, etc.)

Siemens VAI will consequently further develop this technology and the first robot of this kind has successfully gone into operation in November 2007 in South Korea with a limited number of functions but with the possibility of later upgrades. The next LiquiRob installation will be implemented in another slab caster of a South American steel producer in the Spring of 2008. At a different steel works, a modified version of LiquiRob will be employed for sublance-probe handling of the steelmaking converters.
The whole concept follows the successful philosophy of mechatronic packages with “connect and cast” ability and modular extension capability.
Finally, it is expected that safety standards will improve over time and from a certain stage of technological development onwards no operator will be allowed to work in dangerous environments, especially not in areas with imminent danger that results from handling liquid steel above floor level.

References

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