AUTOMATION SOLUTIONS FOR LADLE GATE APPLICATIONS[1]

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Abstract
The increased demands of today's steel industry for automation solutions throughout the whole process line is growing rapidly. The main driving aspect for automation on the casting platform is the safety of the operation personnel. Semi-automatic coupling of the ladle shroud by means of manipulators is widely recognised as state-of-the-art. However, coupling of the ladle gate cylinder is mainly done manually by the operators at imminent danger. The paper presents INTERSTOP's automation solutions to meet the increasing safety regulations for the casting platform. Further important parameters for automation are process reliability and costs. Whereas safety is the main focus on the casting platform, process reliability and costs come in as general key issues for ladle gate operation. An improvement of process reliability can be obtained by automation of the ladle gate preparation at the ladle preparation area. The paper explains the philosophy that stands behind this INTERSTOP concept based on the state-of-the-art CS ladle gate system and an exemplary layout of the ladle preparation area. Chances, risks and future opportunities are addressed and the potential on cost reduction is shown in detail.
Keywords: Automation; Auto coupling; Ladle gate; Process reliability.

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INTRODUCTION

Stopinc AG is developing automation solutions to complement its INTERSTOP flow control systems of ladle gates, tundish gates as well as converter tap hole gates in close cooperation with RHI AG. Stopinc's and RHI's main focus is to provide automation-ready process solutions for both, mechanics and refractories.
Together with selected partners for automation solutions for specific tasks have been realized or are being developed. A result of this is the joint development with MTAG Marti-Technologie AG, Switzerland for the worldwide first manipulator of a fully automatic ladle gate cylinder handling system, which is successfully in operation at SSAB Tunnplat in Lulea, Sweden.(1)
Robotic applications for coupling of the ladle gate cylinder to the ladle gate and coupling of the ladle shroud to the exchangeable ladle gate nozzle are being developed together with partners such as Siemens VAI Metals Technologies GmbH & Co and others.
The paper reviews the main driving aspects for automation and overviews existing and upcoming automation solutions with focus on the casting platform and on the ladle preparation area.

KEY ASPECTS FOR AUTOMATION

Safety

In terms of safety for the operation of the ladle gate equipment special attention has to be paid to the casting platform and to the ladle preparation area.
The first task for the operator on the casting platform to prepare the ladle for casting is the coupling and locking of the ladle gate cylinder to the ladle gate on the turret. Further common activities to be carried out underneath the ladle are the coupling of the slag detection connection and the coupling of the cooling media. Working besides the ladle the operator is exposed to sudden splashes of liquid steel or slag and of steel residuals.
More obvious is the danger and the harsh conditions for the operators when coupling the ladle shroud to the exchangeable nozzle of the ladle gate. Besides steel and slag splashes, the exposure to heat and the awkward position of the ladle gate at this stage above the tundish makes manual coupling of the ladle shroud extremely dangerous. Therefore, remote but manual handling of the ladle shroud and, more sophisticated, semi-automatic solutions are state-of-the-art and widely in operation.
As a consequence of this imminent danger for operators the currently applied European standard EN 14753 Safety of machinery - Safety requirements for machinery and equipment for continuous casting of steel is defining safety requirements, which will force steel producers and suppliers to provide automation solutions to ensure the safety of the operation personnel. In fact, European steel producers and equipment manufacturers already consider the new EN 14753 standard for the layout and evaluation of new continuous casting machines.
The safety requirements at the ladle preparation area are less demanding than on the casting platform due to the absence of liquid steel. Nevertheless, O_2-lancing and breaking out of refractory parts produce splashes, fumes and dust. Manual handling of heavy loads and the presence of high heat radiation lead to harsh working conditions. Operators at the ladle preparation area are exposed to a potential risk of being injured or facing severe health problems on a long term.

Process reliability
The demanding working conditions for operators at the ladle preparation area can lead to a reduction in quality of the tasks carried out. For example incorrect setting of the ladle gate refractories may lead to a break out of liquid steel in the worst case, which can not only be hazardous for the equipment but can also be fatal for operation personnel. Uncareful O_2 lancing, insufficient nozzle cleaning or improper refractory setting may reduce the lifetime of the refractory components resulting in higher costs.

Financial issues
Automation of tasks on the casting platform is clearly driven by safety concerns and will lead to additional costs due to investment in automation equipment and resulting in extra operational effort. For the ladle preparation area the situation is basically different. The cost saving potential is based on a reduction of the operation personnel and on the benefits regarding improvements of the process reliability. Whereas the cost saving on the base of a reduction of the manpower can easily be quantified, the cost saving potential of the higher process reliability can only be estimated qualitatively.

Findings
Automation is the key solution to meet the different requirements of safety, process reliability and cost issues for ladle gate applications on the casting platform and at the ladle preparation area.

AUTOMATION ON CASTING PLATFORM

Automatic coupling of the ladle gate cylinder to the ladle gate
The operators work to couple the casting cylinder to the ladle gate includes a manual lateral insertion of the casting cylinder flange to the ladle gate cylinder bracket. Simultaneously, the operator adjusts the position of the casting cylinder piston rod to the position of the ladle gate push rod by hydraulically controlling the piston rod via a pendant (Figure 1). Thus, for the automation of the coupling process of the ladle gate cylinder to the ladle gate the task can be divided into two steps:

1) Mounting of the ladle gate cylinder to the cylinder bracket
2) Coupling to the push rod of the ladle gate

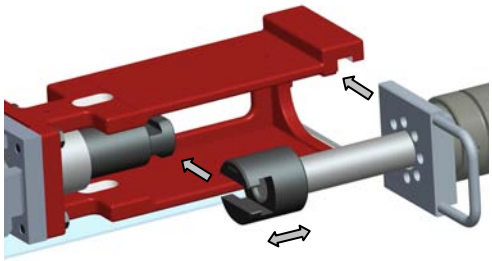

Figure 1: Manual coupling procedure

This separation of the functions helps finding easy to apply technical solutions as a simultaneous automatic procedure of both steps would require sensitive equipment like sensors and would result in additional technical effort.
Depending on the application additional tasks are carried out by the operator:

- Locking of the casting cylinder

- Coupling of the slag detection signal cable
- Removing of the transportation locking device
- Unlatching of the tilting device

Of course, all automation solutions of the above described functions and tasks need to be designed for the reversible operation of the whole process.

First step: Mounting of the ladle gate cylinder to cylinder bracket

Major issue for the mounting of the ladle gate cylinder to the ladle gate is the position detection of the cylinder bracket. Due to a number of influences the position of the cylinder bracket varies for each coupling cycle. The cylinder bracket position depends on:

- Position of the ladle on the ladle turret (offset horizontally, offset angle horizontally and vertically)
- Angular position of the ladle turret
- Range of geometrical tolerances of ladle
- Position of the ladle gate at the ladle
- Variation of total load of ladles

Another issue is the handling of the casting cylinder itself. Two basic ways of automatic handling are known:

a) Customized manipulator as a part of the ladle turret arm where the manipulator remains connected to the casting cylinder during casting.
b) Standard robot as a part of the casting platform where the robot is disconnected from the casting cylinder during casting.

Each handling concept uses different position detection solutions. The first fully automatic coupling of the casting cylinder at SSAB Tunnplat in Lulea, Sweden makes use of a customized, purely mechanical centring system (Figure 2).[1] The manipulator is fixed on the ladle turret arm. It swivels the casting cylinder attached to a compensation unit underneath the ladle by 90°, re aching the same axis as the drive of the ladle gate. In the following, an upward movement together with a pre-centring ensures an exact positioning of the casting cylinder. This handling concept is successfully in operation since 2005.

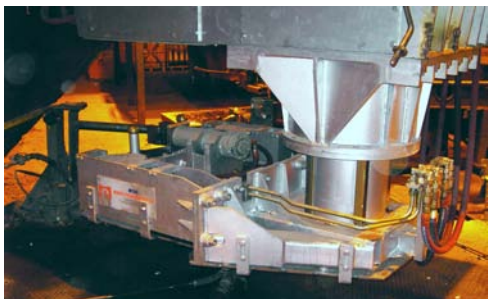

Figure 2: First fully automatic coupling of the casting cylinder.

In the meantime robotic handling solutions on the casting platform have become state-of-the-art for measuring, sampling and applying powder at the tundish. Along with that, optical systems for position detection have been further developed and are now available for robotic solutions e.g. LiquiRob® (patent pending) (Figure 3).[2] Therefore, the range of tasks carried out by robots will include automatic coupling of the casting cylinder in the near future.

Figure 3: Position detection of LiquiRob® (LiquiRob® is a registered trademark of Siemens VAI)

Second step: Coupling to the push rod of the ladle gate

With the casting cylinder positioned and locked to the cylinder bracket the next step in the procedure is the connection of the piston rod of the casting cylinder to the push rod of the ladle gate.

Here, INTERSTOP's well established SNAP coupling technology fulfils the requirements of a reliable, easy to apply connection ideally. The SNAP coupling is an innovative solution for a safe coupling to the push rod (Figure 4). Besides the SNAP coupling application with the previously described manipulator at SSAB Tunnplat, the SNAP coupling is in operation at several steel plants for an easy manual coupling of the casting cylinder on the casting platform and of the mounting cylinder at the ladle preparation area.

]Figure 4: Application of SNAP coupling.

The cylinder head of the cylinder is equipped with the two claws of the SNAP coupling. The proved concept is based on the complementary set-up of spring forces, claw geometries and materials. For the coupling process the SNAP coupling is pushed forward by the cylinder to catch the ladle gate push rod. Decoupling is performed by moving out the cylinder sideways (Figure 5). This movement is either done by a manipulator or a robotic solution according to the described handling concepts. The SNAP coupling also allows an easy coupling of the mounting cylinder for the automation concept of the ladle preparation area.

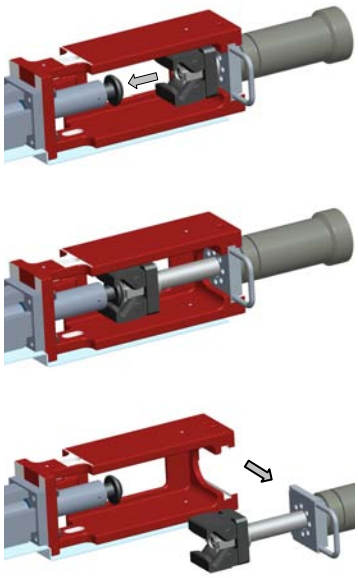

Figure 5: SNAP coupling to the push rod of the ladle gate.

Ladle shroud coupling to ladle gate

Driven by safety requirements for the operators the ladle shroud handling, using manually operated or semi-automatic manipulators, is state-of-the-art. A full automation including exact positioning of the ladle shroud at the exchangeable nozzle is depending on a reliable detection of the exchangeable nozzle position, which, under steel plant conditions, has been a challenge in the past. So far, ladle shroud manipulators are brought to the final position manually controlled by a joystick. Further, the manipulator remains connected to the ladle shroud during casting and applies a defined upward force on the ladle shroud to seal against the exchangeable nozzle. The manipulator axes are released to allow horizontal displacement in order to prevent any lateral forces on the exchangeable nozzle due to the ladle gate movements. Despite this, remaining lateral forces reportedly cause problems at the connection ladle shroud - exchangeable nozzle leading to break out's at the exchangeable nozzle.

An approach to overcome such problems is to divide the function of coupling of the ladle shroud to the exchangeable nozzle into two steps similar to the situation of coupling of the casting cylinder to the ladle gate:

1) Positioning and interchange of the ladle shroud to the ladle gate
2) Connecting the ladle shroud to the exchangeable nozzle.

First step: Positioning and interchange of the ladle shroud to the ladle gate

Again, reliable position detection is the key for successful positioning and interchange of the ladle shroud to the ladle gate. The same technology as for the position detection of the coupling of the casting cylinder can be applied. The ladle shroud is than transferred from the ladle shroud handling device to a specially designed ladle shroud clamping device which is part of the ladle gate.

Second step: Connecting the ladle shroud to the exchangeable nozzle
The ladle shroud clamping device of the ladle gate includes an additional drive. The coupling of the clamping device to the ladle gate is done in a similar way as the coupling of the casting cylinder to the cylinder bracket. The drive allows a very accurate definition of the force to press the ladle shroud to the exchangeable nozzle. Together with modern ladle gates featuring only two main parts the ladle shroud clamping device remains relative to the exchangeable nozzle always at the same position. This allows a very simple and reliable design of the ladle shroud clamping device (Figure 6).

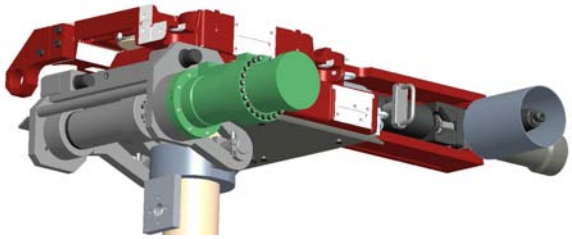

Figure 6: Ladle shroud clamping device.

Connection of ladle shroud – exchangeable nozzle as a part of the ladle gate
The advantages of implementing the connection of the ladle shroud – exchangeable nozzle into the ladle gate are obvious:

- No external influences to the connection ladle shroud – exchangeable nozzle such as lateral forces.
- Clearly defined force for pressing the ladle shroud against the exchangeable nozzle.
- The handling device stays available for other tasks during casting. This is important for applications of robotic solutions on the casting platform.

This system was originally developed by Siemens VAI Metals Technologies GmbH & Co (patent pending) and has been adapted by Stopinc to INTERSTOP's ladle gate CS.

Outlook
Both, automatic coupling of the casting cylinder and the ladle shroud will help to increase the safety of the operation personnel on the casting platform. The technologies are being developed by Stopinc based on INTERSTOP's SNAP coupling and ladle gate CS. Applications of automatic coupling solutions for ladle gates on the casting platform will be operational in short terms.

AUTOMATION OF LADLE GATE PREPARATION

The ladle preparation area is an often neglected area in steel plants, despite its utter significance for safe operation of the ladles within the steel work. Mostly positioned at places with harsh working conditions where the operators are exposed to fumes, dust and high temperatures. Moreover, the tasks for the operators to carry out are exhausting and rather disregarded compared to the tasks on the casting platform. Consequently, incorrect ladle gate preparation may lead to a reduction of the

refractory life time and, in the worst case, to severe breakouts. Further, incomplete work at the ladle preparation area may cause severe economical losses, since a not closed ladle gate leaving the ladle preparation area will lead to a loss of liquid steel at the tapping station. Together with the given costs of labour and infrastructure, additional costs arise caused by such incidents, not considered the danger to the operation personnel.

Automation system for ladle preparation area

Based on these issues the idea of a fully automated ladle preparation was born. All tasks at the ladle preparation area, beginning from changing of the exchangeable nozzle to the replacement of the purging plugs (or even to the gunning of the ladle) should be reliably carried out by an automation system (Figure 7).

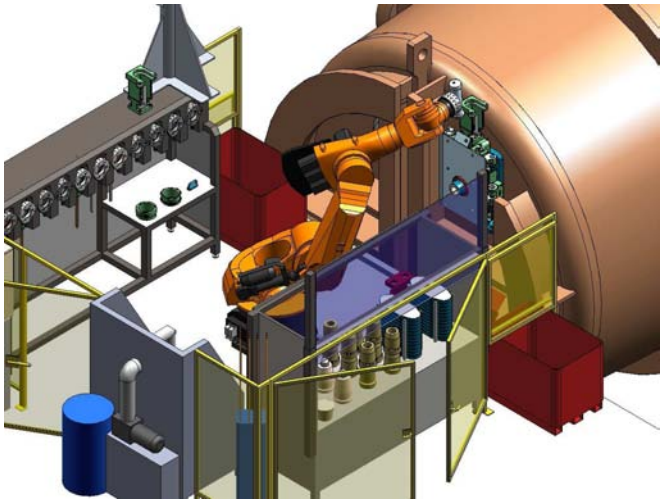

Figure 7: Fully automated ladle preparation area.

A standard 6 axes industrial robot is the main item of such a system. A tool changing system allows the use of a wide variety of tools. Together with standard robotic claws for refractory components, various specific tools are used e.g. tools for cleaning of the casting channel or tools for changing of the inner nozzle. Where needed, mortar could be applied on the refractory parts in a specifically designed mortar station. Wear parts, e.g. O_2 lances, and the needed refractory components are supplied by a spare parts store. These spare parts would have to be refilled periodically by an operator.

The position of the ladle gate or the purging plugs at the ladle bottom is indicated automatically by the system. The robot's flexibility offers the possibility to adjust the system to the actual ladle position. Therefore, accurate positioning by crane or special maintenance of the ladles is not necessary. Used parts and waste is deposed in recycling bins which can be disposed by the operator without interrupting the automation system.

Modularity

A task specific tool design offers the possibility to adapt the functional range to customer's needs. For example, stand alone systems to change the inner nozzle or to clean the casting channel can be operated on existing ladle preparation areas. However, the full potential of automation tools is apparently given only by a complete automation system.

Sequence of ladle preparation

After the ladle is placed at the preparation area the sequence (Figure 8) is started by the operator.

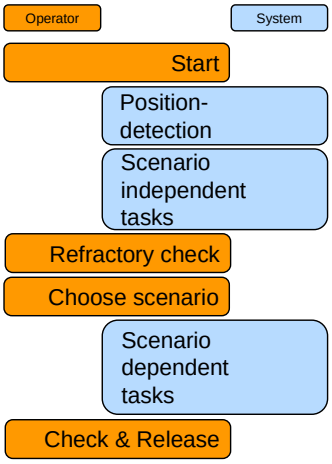

Figure 8: Sequence of ladle preparation.

First step, the ladle's actual position in the ladle stand is detected. This information is used for all tasks to be performed.

Subsequently, basic tasks to prepare every ladle such as cleaning (O_2 lancing) of the casting channel, testing of the purging plugs etc. are executed.

Next step is that the operator has to check the condition of the refractory parts. This check is equally done as today and the operator specifies the parts to be replaced and chooses the corresponding scenario. The system subsequently performs the relevant tasks as changing of the plates or changing of the inner nozzle.

After the system completes its work the ladle is assessed and released by the operator.

Automation-ready ladle gate

A requirement for a reasonable automation of the ladle preparation area is the use of automation-ready equipment as INTERSTOP's ladle gate CS. This type of ladle gate offers a variety of benefits for automation systems:

The mounting cylinder with SNAP coupling enables an easy connection to the push rod of the ladle gate (Figure 9).

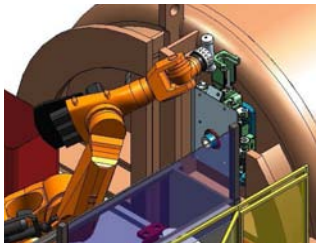

Figure 9: Coupling of mounting cylinder with SNAP coupling.

A change of the exchangeable nozzle without opening of the ladle gate is possible. The exchangeable nozzle can be mounted / dismounted by an easy-to-apply rotation of the nozzle holder.

The system tension has to be released to change the refractory plates and the inner nozzle. With modern INTERSTOP ladle gates in general, the tension can

automatically be released by using the extra stroke of the mounting cylinder. No additional device, tool or further action by the robot is needed. After the system tension is released, the ladle gate can be opened directly by the robot. The design of the CS type ladle gate with only two main parts and a large swivel range offers sufficient access to the refractory parts (Figure 10).

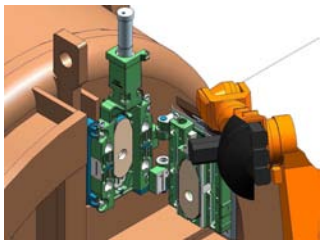

Figure 10: Access to refratory parts.

The setting of the inner nozzle is eased by a defined stop of the refractory part in the housing of the CS ladle gate. On one hand the inner nozzle is therefore clearly positioned and on the other hand this stop ensures a clearly defined mortar joint between the inner nozzle and the bottom plate. This allows an easy to apply coating of the mortar on the bottom refractory plate in the foreseen mortar station (Figure 11).

Figure 11: Mortar station.

Due to the canned refractory plates and the CS ladle gate centring system the plates could be easily placed into the ladle gate (Figure 12). No further actions by the robot are needed.
These examples explicitly show the specific advantages of the INTERSTOP state-of-the-art CS ladle gate for the automation of the ladle preparation area.

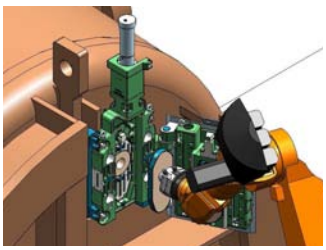

Figure 12: Automation-ready ladle gate CS.

Advantages of an Automation of the ladle Preparation area

The following advantages are offered by an automation system:

- Cost savings due to higher process reliability
  For example the automation system ensures that the ladle gate is in closed position when the ladle leaves the preparation area.

- Cost reduction due to less operational efforts
  A reasonable return on invest (ROI) is achieved by a reduction of labour costs.
- Increased operational safety is achieved due to constant high quality of the ladle preparation.
- Potentially dangerous tasks for operators such as O_2 lancing or handling of heavy loads are performed by the automation system.
- The accomplishment of performed tasks is recorded and can be statistically used for quality management issues.

Operation of an automation system on the ladle preparation area

An automation system on the ladle preparation area involves significant changes to this part of the steel plant. Manpower is still needed but can be reduced substantially. Besides the operation of the automation system the operator's responsibility is focused on checking the condition of the refractory parts and assessment and release of the ladle. The tasks to be done by the operator change from heavy physically work to surveying the system including trouble shooting of minor errors.

A very high availability of the automation system is required. A serious system breakdown can endanger the steel production. On one hand a high availability is achieved by a fault-tolerant design of the system and on the other hand a consequently performed maintenance of the whole system is essential. Preventive maintenance of different tools and components is compulsory and an infrastructure to allow quick trouble shooting needs to be available. Depending on the steel plant's maintenance organization such duties can be handled either in-house or with an external partner company. Worldwide infrastructure and services of robot distributors could also be used. Remote access to the automation system via internet offers another opportunity to support qualified local operators by specialists.

Outlook

Stopinc's vision is a fully automated ladle preparation area. Technical concepts and economical considerations have already been evaluated. At the moment R&D activities concentrate on optimization of process solutions for automation. Current projects focus on automation of the changing of the inner nozzle on a capable position detection system and on tools for automatic casting channel cleaning. These projects show the wide variety of topics involved in the development of such a system ranging from refractory research to sensor development.

Within the next two years Stopinc will be able to provide modules for the automation of specific tasks such as the cleaning of the casting channel or the changing of the inner nozzle. A complete automation system will be introduced to the market subsequently.

SUMMARY

Ladle gate specific tasks on the casting platform and at the ladle preparation area are potentially due for automation in the near future. Driving features are safety with the focus on the casting platform and process reliability and financial aspects at the ladle preparation area.

Stopinc and RHI together with other partners are developing solutions to satisfy the upcoming need for such automation based on INTERSTOP's SNAP coupling and automation-ready CS ladle gate.

In short term robotic solutions for an automatic coupling of the casting cylinder and the ladle shroud to the ladle gate will soon be operational. In mid term automation solutions for the ladle preparation area will be presented.

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