Reinhard Ehrengruber, Verena Schmidt, Raphael Renggli and Maximilian Jani

INTERSTOP Automation, Robotics and Digitalisation Solutions for Flow Control Technology

A major trend in continuous steel casting is the upgrade of flow control systems to meet new market demands. In addition to supporting clean steel production, ease of handling, and economic benefits, flow control systems must be designed to enable automatic and robotic operation. One reason for this is operator health and safety, while another is to ensure that critical process areas such as the ladle preparation area and continuous caster remain operational and become more attractive workplaces for the next generation of personnel. This article describes how INTERSTOP automation, robotics, and digitalisation solutions are setting standards in flow control and which products are now being introduced in the steel industry.

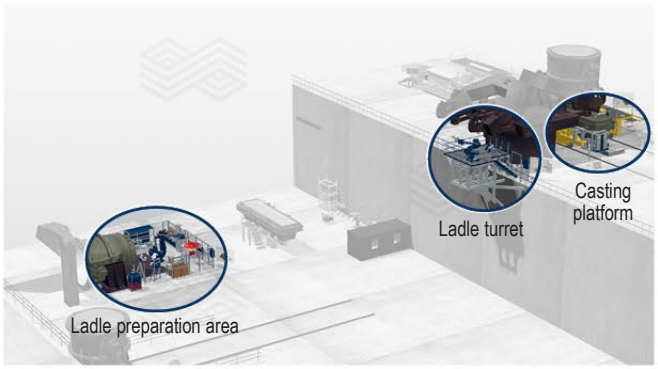
Introduction

The steel sector in general and the flow control area more specifically are undergoing a major change. In the past, a stable production process had by far the highest priority and the execution of manual activities in working areas critical for personnel due to hazardous conditions were subordinated to this. Systems were designed with handling ergonomics, clean steel support, ease of maintenance, and low operating costs in mind. However, the workers' interactions with the flow control systems and handling of the involved refractory parts play a crucial role for stability of the casting process on the continuous casting machine (CCM). Therefore, the following main tasks are being addressed by automation solutions (Figure 1):

- Inspection and maintenance of the ladle slide gate at the ladle preparation area.
- Connection of the casting cylinder and electrical plug for the slag detection system, as well as coupling shielding media like argon and/or cooling air from the ladle turret of the CCM to the ladle slide gate.
- Monotube exchange and mould powder feeding on the casting platform of a slab casting machine.

Figure 1.

Areas for the INTERSTOP flow control automation solutions in the steel plant.



In recent years, the requirements for flow control systems have radically changed and technologies like robotic cells and digital tools are being adopted to perform these operations automatically. As a result, the workers' role is transformed from operator to supervisor of the robotic operation. The advantages of introducing robotic operation and digital tools in these areas are:

- Increased occupational safety as entering hazardous areas and manual handling of heavy loads are eliminated (complying with stricter safety laws).
- Precise and identical handling of the equipment and critical parts such as a heated monotube. This eliminates damage during handling or premature wear due to poor manual handling of electrical connectors for example.
- Improved decision-making leads to higher operational reliability and lower costs. The enabler for this is replacement of individual, experience-based decisions with fact-based, decision-support systems.
- Processes can be continuously improved by collecting and analysing data with algorithms. The introduction of robots into the operation and digitisation into decision-making also means that process knowledge remains available even when experienced employees retire. In addition, the digital system is able to learn by adapting its parameters to unforeseen events.
- The steel mill creates an attractive workplace where engineering skills are needed. In recent discussions with steel plant managers, it was always specifically emphasised that on the one hand it is difficult to fill the shifts due to the risk of injury and on the other hand there are hardly any young people interested in these jobs.

Therefore, INTERSTOP developed the core enablers to implement these technologies in the steel plants. These can be subdivided into:

- Automation-ready flow control systems.
- Position detection system.
- Health Check Platform.

Automation-Ready Flow Control Systems

In the past INTERSTOP systems were optimised for human operation. However, a robot works in a fundamentally different way to a human, for example it does not have two hands and can move much heavier loads with high precision. Therefore, one principle that was applied to the design of the automation-ready INTERSTOP systems is they must remain both ergonomically operable for humans and enable automated handling by robots. As a result, implementing robotic cells enables dual operation by humans and robots without interrupting operations. Furthermore, it allows quick manual intervention if the robotic cell has an operational interruption. The mechanical systems focused on were:

- INTERSTOP SX/AS ladle slide gates to enable robotic handling of the casting cylinder on the CCM, the so-called media coupler (MC), as well as robotic operation at the ladle preparation area.
- INTERSTOP MTC monotube changer ready for robotic monotube handling (MTH).

The following is a summary of these systems, which have previously been described in detail [1].

INTERSTOP SX/AS ladle slide gates

The SX ladle slide gate stands for:

- User-friendly design for fast, safe, and simple operation.
- Easy and quick handling at the preparation area.
- Low operational costs and high performance.
- Readiness for automation and robotic operation.

With the SX, several robotic operations can be performed on the CCM and at the ladle preparation area. However, to unlock the full automation potential the AS slide gate was developed that allows the robotic handling of all slide-gate-related refractory parts at the ladle preparation area (Figure 2).

INTERSTOP media coupler

The MC ensures a quick and easy connection of the casting cylinder at the CCM to the slide gate, after the ladle is put into the loading position at the ladle turret. On the slide gate side, no parts need to be manipulated as the transport lock and cylinder locking system are activated “on the fly” by moving the cylinder in or out. This drive carries the slag connector plug as well as two pneumatic lines for cooling (e.g., compressed air) and/or sealing (e.g., argon) purposes (Figure 3a). On the cylinder side, the main features include the SNAP coupling, the cylinder locking system, slag connector plug, and the couplings for compressed air and/or argon (Figure 3b). Application of the automation-ready design on the MC has also greatly simplified manual handling, resulting in increased occupational safety and process reliability.

Figure 3.

(a) standard SX ladle gate with adapted drive for MC and (b) corresponding cylinder with integrated features for the MC operation.

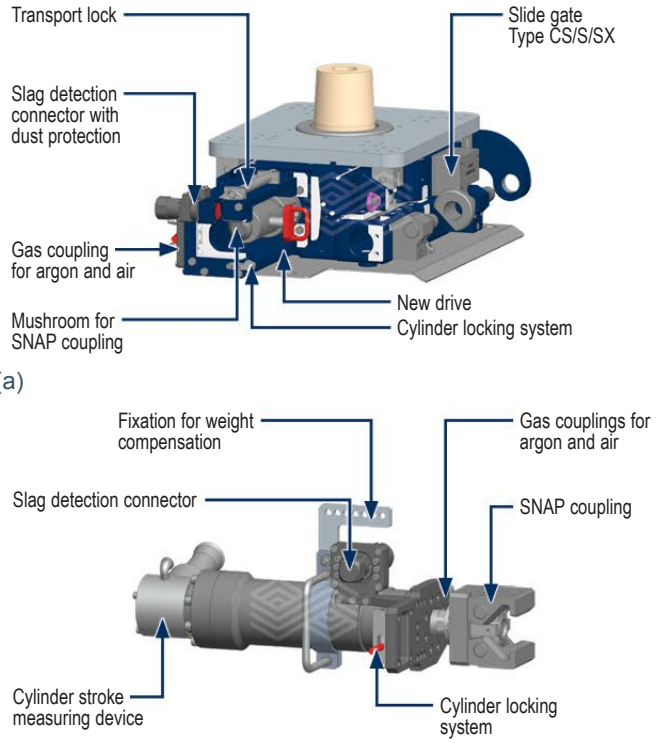
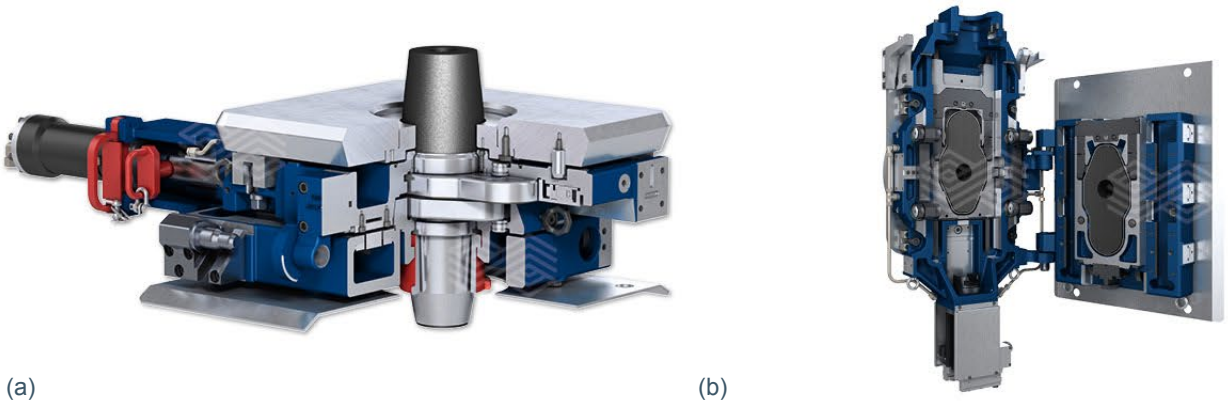


Figure 2.

(a) standard SX ladle gate and (b) AS ladle gate to unlock the full automation potential at the ladle preparation area.



INTERSTOP MTC monotube changer

The main benefits of the MTC monotube changer (Figure 4) are:

- No blind plate handling is necessary as the blind plate is integrated in the mechanics and automatically activated.
- No cylinder handling is necessary as the cylinder and drive is sideways.
- Reduced size and weight of the system.
- Readiness for automation and robotic operation.

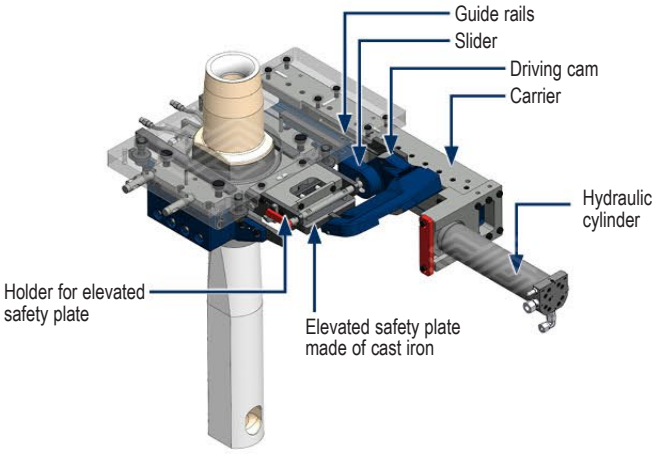
Position Detection System

To enable a robotic operation and achieve permanent high availability, a reliable measuring system is essential. This system must ensure that the robot always receives precise coordinates of where to place the tools and the mechanical or refractory parts; the required accuracy is <1 mm for reliable continuous operation. The measuring system must also ensure that fluctuations occurring in the steel plant regarding distances between the measuring system, robot, and slide gate system mounted to the ladle bottom are compensated. These fluctuations are caused, for example, by thermal expansion due to different temperatures. Furthermore, the measuring system must be immune to changes in the available light (e.g., day, night, spotlights, and sunlight through windows) as well as dust and steel splashes.

Up to now, various measuring systems have been used for flow control applications and most of them have one thing in common: The measurement reference is an externally mounted target. However, this method is susceptible to the influencing factors described earlier. The INTERSTOP in-house development overcomes these issues as no external target is required. Measurement by a stereoscopic camera delivers a point cloud that is matched with the 3D CAD model of the slide gate system (Figure 5). This technology is the basis for extremely high accuracies even under changing external conditions.

Figure 4.

MTC monotube changer system with the integrated safety plate and off-centre drive arrangement.



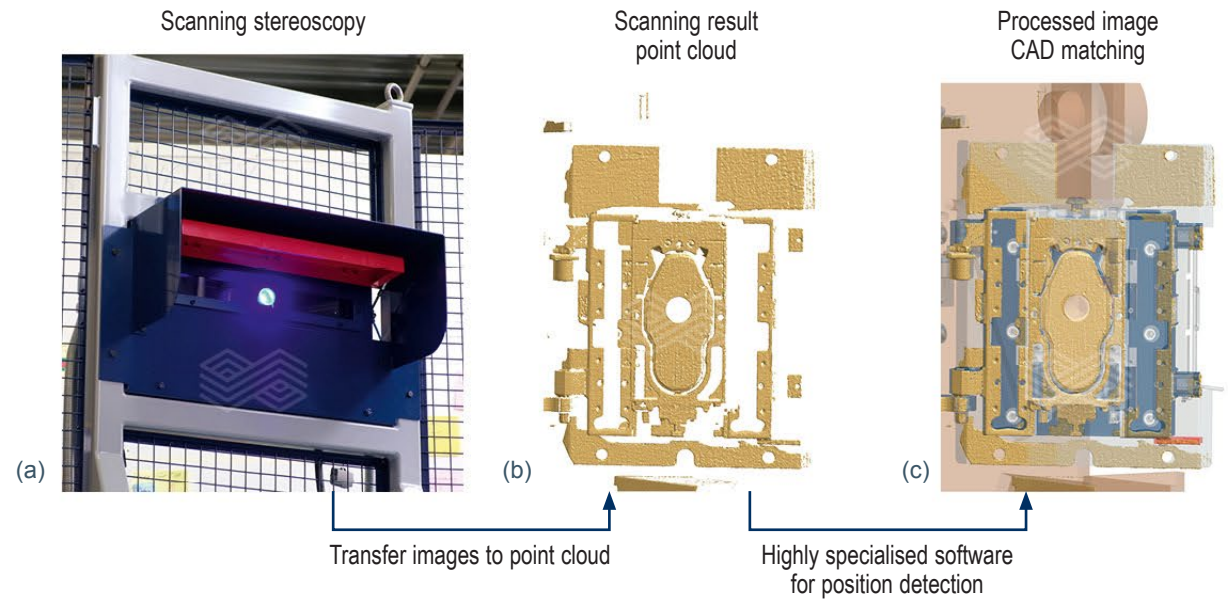
Health Check Platform

The Health Check Platform (HCP) is being developed to inform users about the condition of the mechanical and hydraulic systems as well as the refractory parts, especially at the ladle preparation area. Furthermore, it supports personnel in deciding which next steps to take, for example exchange of slide gate plates. The HCP considers data received from own measurements taken at the ladle preparation area and the CCM as well as from customer Level 1 and Level 2 data (Figure 6). The implementation of the HCP takes place in 2 phases:

- Phase 1: Learning and teaching phase where data sets including 3D scans of slide gate plates are collected and are the basis on which the algorithms are trained.
- Phase 2: Optimisation phase where the algorithms and machine learning are refined based on the phase 1 data sets and the ongoing received data.

Figure 5.

Position detecting system, consisting of the (a) stereo camera, (b) computing of a point cloud, and (c) matching with the CAD data.



The benefits of the HCP are:

- Replacing experienced-based individual decisions with machine-learning-based decision support.
- Preventing malfunctions.
- Precondition for the highest level of ladle preparation area automation (LPA) operation.

Based on the three core technologies described above, the following automatic and robotic solutions are currently being introduced to the market.

Ladle Preparation Area Automation

At the ladle preparation area, performance strongly depends on individual operator skills and experience. The heat load is high and operator safety is a constant issue. These circumstances have a direct influence on the reliability of the tasks performed [2].

Furthermore, the workers act in the tension between safety and cost considerations. One heat more on a slide gate plate saves costs, but a wrong judgement could lead to a substantial accident on the CCM during the next heat.

The INTERSTOP LPA provides robotic operation of the ladle preparation area and the core functions are (Figure 7):

- Cylinder handling and oxygen lancing.
- Handling of slide gate refractory parts.
- Inner nozzle surface cleaning.

The advantages of the LPA are:

- Safety—get operators away from liquid steel, heat, dust, and time pressure.
- Process stability—high reliability of tasks performed.
- Extension of refractory life.
- Data acquisition for predictive maintenance and lifetime prediction models.

Figure 6.

Overview of the HCP in phase 1 where 3D data is collected by a robot for a short learning phase to teach the algorithms.

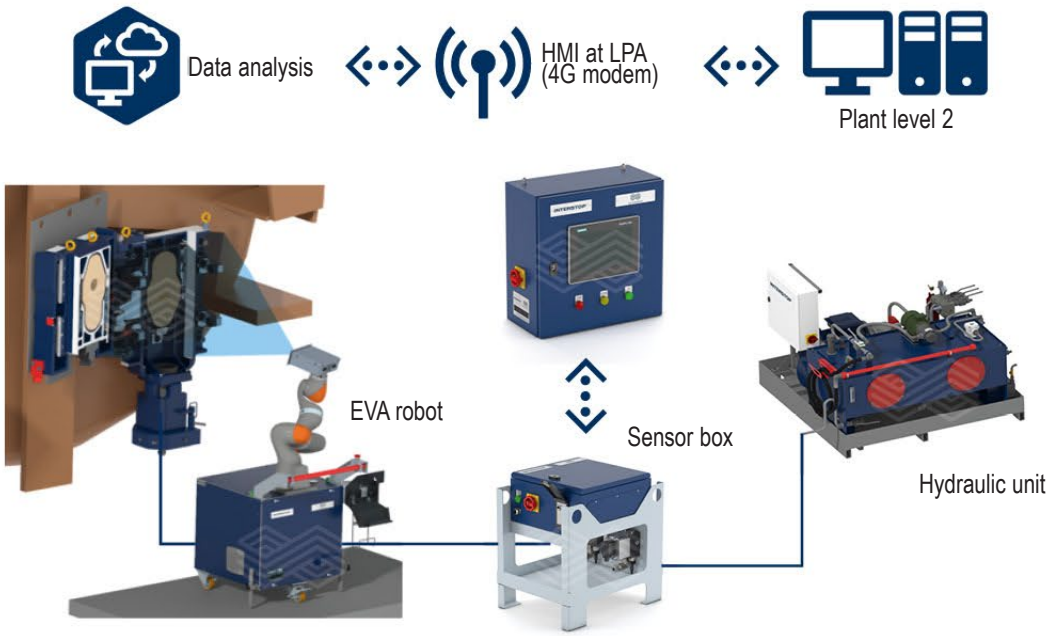
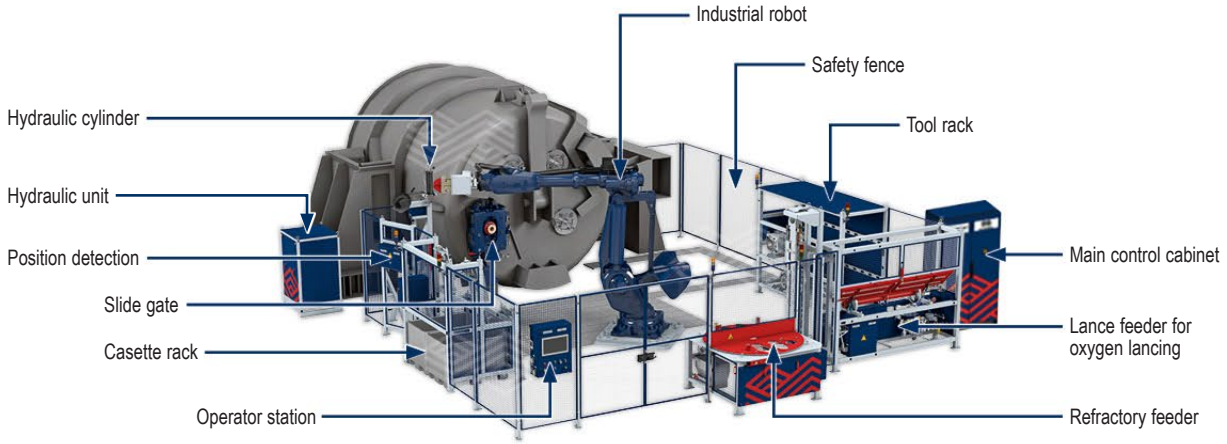


Figure 7.

Overview of the LPA robotic cell and main components.



Robotic Cylinder Handling and Integrated Media Coupling

Robotic cylinder handling (CYL) and integrated MC on the CCM is designed to keep the operator away from the danger zone under a full ladle. Since the hydraulic cylinder, process gases, and slag detection are coupled with one movement, the robotic operation of this system is significantly faster than conventional handling. Besides this, the manual operation is also improved, with one single movement in or out the cylinder is coupled and the media are connected.

The core functions of the CYL are (Figure 8):

- Robotic solution for fully automatic connection of the slide gate casting cylinder to INTERSTOP systems on the CCM.
- Coupling and uncoupling media like argon, cooling air, and electric connectors for slag detection systems.

The advantages of the CYL are:

- No-man operation on the ladle charging area—a robot fulfils the operator's tasks in the harsh environment.
- Enhanced health and safety standard.
- Increased efficiency and process control.

Robotic Monotube Handling and Mould Powder Feeding

Monotube changers are common on CCMs for slab casting. They enable extension of the sequence in case of monotube wear or the occurrence of clogging. The procedure of manual monotube exchange is an exhausting activity for the operators involved. A hot monotube of >20 kg must be handled with care to avoid damaging the ceramic and to avoid unnecessary disturbance of the mould level when inserting the monotube. After the monotube change, the used monotube must be taken out and moved to the waste container. Besides handling the monotube, operators must take care to feed the correct amount of mould powder into the mould. The core functions of the MTH are (Figure 9):

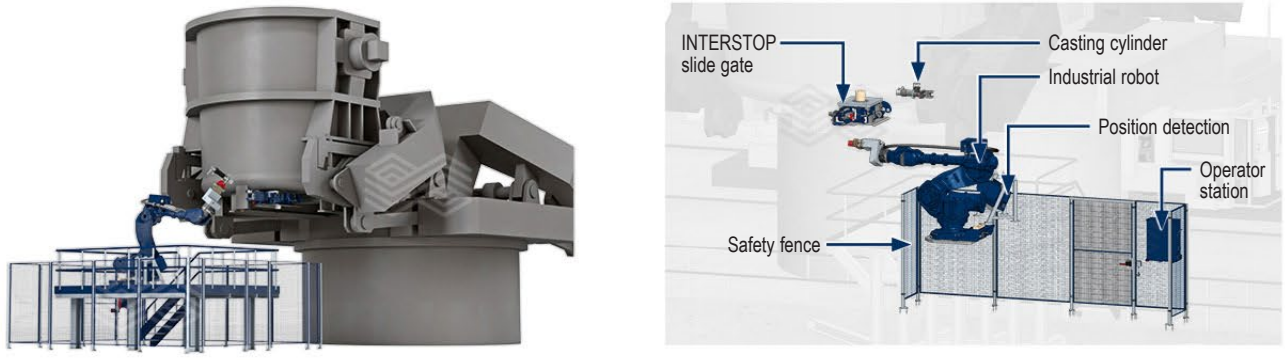
- Heating up the monotube.
- Automatic exchange of the monotube by grabbing the heated-up monotube from the heater and restoring the used monotube to the release station.
- Feeding the mould powder.

The advantages of the MTH are:

- Little space requirements and full front access to the mould with the unique INTERSTOP upside down mounted small robot on the backside of the tundish car.
- No-man operation on the CCM.
- Precise and uniform manipulation of the new and used monotube during exchange.
- Reliable and constant mould powder feeding without interruptions.

Figure 8.

Overview of (a) MC layout at the CCM and (b) main components of the MC.



(a) (b)

Figure 9.

Overview of (a) MTH robotic cell mounted upside down on the backside of the tundish car and (b) main components of the MTH.

(a) (b)

Results/Conclusion

One very important design principle of INTERSTOP is the modularity of the different technologies. Several of the described systems or modules are already in operation at various customers. For example, a steel plant converted the whole ladle fleet to the automatable AS ladle gate, with the intention to now introduce the LPA. Other examples are references for robotic cylinder handling systems, which are operated in several steel plants.

The target of our developments and marketing in automation, robotics, and digitalisation is to provide steel plants with an automation solution for the operation of INTERSTOP flow control systems. For this purpose, we have built up a team of experts that can engineer customer-specific feasibility studies for the robot cells and install complete robot cells on this basis. Furthermore, at our company facilities in Switzerland, we have fully industrial 1:1 mock-ups running of the LPA, MC, and MTH to validate the long-term availability and to present to customers and original equipment manufacturers (OEMs).

In addition to marketing our automation, robotics, and digitalisation portfolio, we are pursuing an open strategy with customers and technology partners such as OEMs regarding the implementation of robotic cells. For example, on the basis of our automation-ready systems we support the option to jointly define the interfaces for the robotic operation with a partner like an OEM.

With the experience gained, the references established, the modularity of our technology, and the marketing strategies chosen, all requirements are fulfilled to provide customers with flow control systems that combine superior manual handling and automatic operation by robots.

References

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[2] Steiner, R., Lammer, G., Spiel, C. and Jandl, C. Refractories 4.0. *BHM Berg- und Hüttenmännische Monatshefte*. 2017, 162, 11, 514–520.

Authors

Reinhard Ehrengruber, RHI Magnesita Switzerland AG, Hünenberg, Switzerland.
Verena Schmidt, RHI Magnesita Switzerland AG, Hünenberg, Switzerland.
Raphael Renggli, RHI Magnesita Switzerland AG, Hünenberg, Switzerland.
Maximilian Jani, RHI Magnesita Switzerland AG, Hünenberg, Switzerland.
Corresponding author: Reinhard Ehrengruber, Reinhard.Ehrengruber@rhimagnesita.com