Gunning automation to improve safety and quality of repairs

The hot gunning repair of refractories for converters, ladles, EAFs, RH-snorkels, etc., is a cost saving alternative to a shut down and renewal of the complete lining. This process increases the service life of a furnace considerably and it further results in savings in reheating energy. Due to the quick repair, the number of circulating refractory lined vessels, for example ladles, can also be reduced.

The use of gunning manipulators is necessary to improve the working conditions of operators. They allow a more well directed repair to specific positions and higher gunning capacities than manual gunning. It is also possible to reduce considerably the repair time and loss of heat of the refractories, saving money on refractories and reduced downtime. Moreover, risk of an accident is reduced. However, melt shops are not identical and gunning robots have to be customized for optimum performance.

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LADLES

The typical refractory consumption for ladles is 0.2kg/t steel at the bottom and side wall and 0.4kg/t steel in the slag zone. When checking the lining it is often found that only the slag zone needs to be repaired. At plants with secondary metallurgy the slag zone wears out more quickly. Sometimes the top of the lining, the lip ring, becomes damaged due to slag removal with a breaking out machine. Consequently, a ladle can be put back into operation very quickly after a gunning repair focused only on the slag zone. In such situations, there is no need to replace the refractories, which are still good to go. There is also no loss of both time and energy to heat and dry a new lining. The most convenient location to carry out a hot repair is the tilting stand, where the slide gate is repaired. It is possible to use a manual gunning lance but this can result in high physical stress in the hot working areas (*Figure 1*).

When using a gunning robot the gunning repair is:

- Quicker, because of higher gunning rates.
- More efficient, because of the well directed jet.
- Easier, because there is no physical stress for the worker.

Velco has built two different solutions for this task, depending on the plant layout. One version is a fixed installation consisting of a rotating lance that can move in and out, running on a beam structure. The robot shown in *Figure 2* has been in operation in a German steel shop since 1987! For each repair stand one robot is required (*Figure 3*).

The second version is a gunning lance which is mounted on an electric trolley that can drive from a parked position to ▷

Fig 1 **Manual gunning of ladle**

Fig 2 **Stationary ladle gunning installation**

Fig 3 **Gunning of the slag zone**

Fig 5 **Ladle gunning robot**

Fig 6 **HYTOP**

Fig 4 **Mobile lance trolley for ladle gunning**

one or more repair positions. *Figure 4* shows a manipulator at a ladle with a liquid content of approximately 150t of steel, for the repair of ladles that are laid on their side, at voestalpine in Linz, Austria. The manipulator is driven in front of the ladle and is operated by a radio remote control. The robot is fed by a pressure vessel gunning machine. The system has a high pressure water pump and electronic water adjustment.

At Outokumpu in Tornio, Finland, VELCO has put into operation a fully automatic gunning installation for ladles while in the upright position (*Figure 5*). The gunning manipulator is located in a specially built hall. Ladles are transported via rail carriage into the gunning hall. There are four gunning positions in total, with different programs for automatic gunning of the bottom, side wall and spout of the ladle. The programs can be started individually, or sequentially without interrupting the gunning process. Two different gunning materials are used: a material for the repair of the permanent lining and a light material for the wear layer. The operator selects the gunning position, the gunning program and the type of material. The gunning process is then carried out automatically.

When changing the gunning material, it is not necessary to exchange the gunning equipment. The operator also has the possibility to take over the manual gunning control via joystick and to gun individually at selected spots. This installation reduces considerably the working strain and dust exposure for the operator. The necessary gunning time is also reduced, as the gunning robot works at a higher gunning capacity and is able to change more quickly between the two different materials.

ELECTRIC ARC FURNACES

In the past 25 years Velco has supplied 20 gunning robots for Electric Arc Furnaces (EAFs). However, due to

Fig 7 **Camera on gunning robot head**

Fig 8 **New design of METOP**

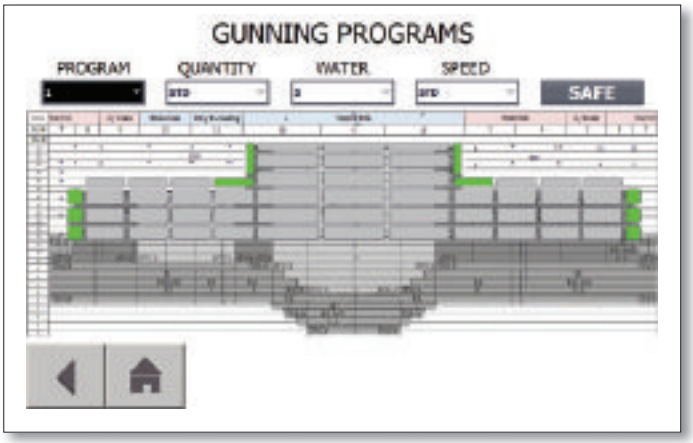

Fig 9 **Zone selection for automatic gunning**

the different layouts of the melt shops no two robots are alike. Moreover, the operating principles of the plants are different. A few plants have the ability to exchange the complete furnace vessel. These plants do minor hot gunning and replace the complete lining every two weeks. Most plants have to keep the lower vessel in place, so an exchange of the lining increases down time dramatically. Hot gunning is the preferred solution to keep the furnace running. When using hand lancing, a pipe of typically 6-8m in length is introduced through the slag door. The gunning rate is only 60-80kg/min. Handling the pipe is hard work and not all areas of the furnace can be reached.

Figure 6 shows the gunning manipulator HYTOP at Deutsche Edelstahlwerke, Siegen for the repair of a 140t EAF. This plant produces stainless steel grades. The gunning nozzle is driven into the requested working position for the open furnace roof. Gunned zones are the slag line, the tapping spout and the door area. The robot is fed by three gunning machines, allowing it to run three different grades of material. The operator starts the gunning machine and controls the repair, by means of joysticks on a radio remote control. There is an option to instal a CCTV camera in the gunning head (*Figure 7*).

A new design developed in 2021 is called METOP. It has a pure mechanical lift system by an electro-mechanical cylinder. No hydraulic is required, as shown in *Figure 8*.

The next step of improvement is the use of pre-programmed gunning programs. The operator can pre-select areas to be gunned using a touch screen. They can save different gunning programs depending on the gunning strategy and furnace life. The robot then automatically repairs only the selected locations (*Figure 9*).

The Lucchini Industries Steel Plant in Lovere, Italy, was looking for a new gunning manipulator to improve operational safety, but had no space near the EAF. They ▷

Fig 10 **PNEUTOP in parking structure**

Fig 11 **PNEUTOP robot moved by a crane**

Fig 12 **Hot gunning repair with PNEUTOP**

Fig 13 **MobiGUN**

Fig 15a **New design of manipulator TR**

Fig 14 **High material loss with manual gunning**

Fig 15b **Gunning manipulator with 2 lances**

decided on the crane held gunning manipulator PNEUTOP, which is parked approximately 40m away from the furnace in a special structure (*Figure 10*). For a gunning repair, the manipulator is picked up by the overhead crane (*Figure 11*) and lowered from the top into the furnace. The PNEUTOP is connected to a pressure vessel machine, which feeds the manipulator and is placed approximately 40m away.

Refractory gunning material is supplied in 'Big Bags' and transferred to the pressure vessel via a filling hopper. The operator uses a radio remote control to move the lance to the desired location, start and stops the pressure vessel machine and control the gunning water flow. Using the gunning manipulator the repair is quicker and operational safety is improved (*Figure 12*).

A stainless steel producer in Italy has two 110t EAFs in the same meltshop. They requested a mobile gunning robot on a self driving carriage. VELCO decided to modify a commercial diesel driven telescopic loader. The MobiGUN parks on the meltshop deck and can access both furnaces. The gunning head is attached to the boom and air cooled by an onboard compressor (*Figure 13*). When driving, the boom is retracted and the gunning head is folded in. For gunning, the boom is expanded and the gunning head is lowered to the furnace from the top. All movements of the gunning lance, water regulation and the start/stop of the gunning machine can be activated with a single radio

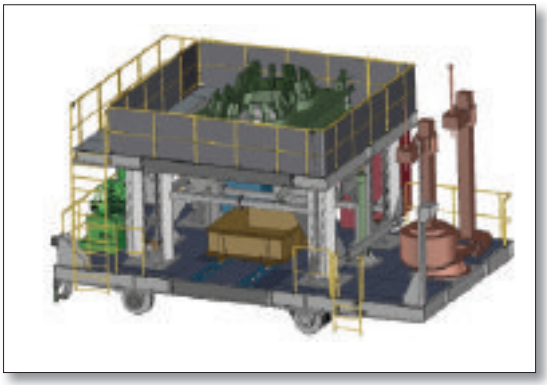

Fig 16 **Service car with scraper and gunning robot (picture from SMS group)**

Fig 17 **Water cooled inspection camera**

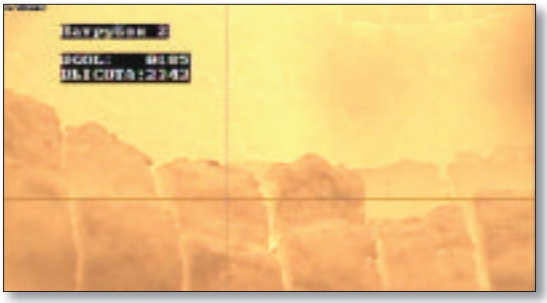

Fig 18 **Inside picture of RH snorkel**

Fig 19 **Gunning robot with two lances**

remote control. The MobiGUN needs only two connections: one to the gunning material hose and a second to the water line.

RH-DEGASSERS

The high quality demands of the automobile industry have led to an increase in the proportion of melts routed via the vacuum degasser. Snorkel lifetime is an important factor in achieving high availability of the RH-degasser. Due to the reaction with steel and slag, the snorkel wears out both internally and externally. Often the outside lining is damaged by slag removal with scrapers, or de-bricking machines. It is of primary importance to keep the system safe and to avoid break outs of hot metal, but the service time is limited as the sequences of the steel plant have priority. Any unplanned exchange of the snorkels should be avoided. Outside gunning is a common practice. However, the workplace is exposed to heat and the operator likes to stay away from the snorkel, so the gunning is not always well directed and has high rebound losses (*Figure 14*).

Some steel plants have a service car to which a platform for hand gunning is attached. Nevertheless, inside gunning is not possible because of the danger of dripping hot steel or slag from the RH-vessel. Hence, using a gunning robot is beneficial for outside repairs, because the gunning is better directed and the physical stress on the workers is

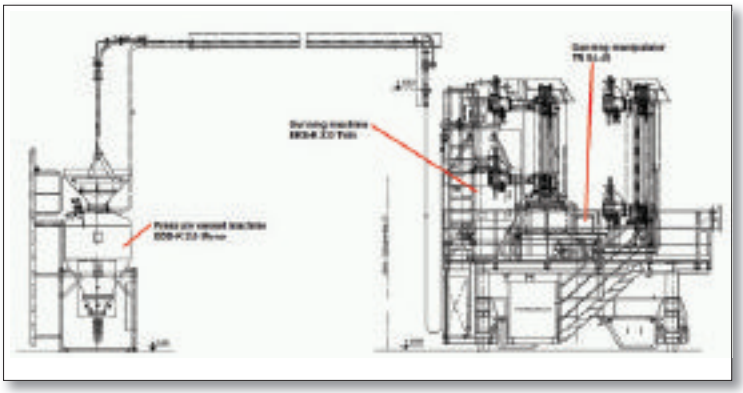

Fig 20 **Automatic gunning installation, on snorkel service car, connected by hose swing**

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GUNNING ROBOTS
FOR IMPROVED
HOT REPAIR
of EAF, Ladle, RH

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reduced. A robot is essential for the inside repair of the RH snorkel. If gunning is performed well, consumption is in the range of 0.5kg/t steel. Typically gunning takes place after six to eight treatments.

Most robots have two gunning lances: one for inside and one for outside repair. Lances and the lifting arm are on a frame that can rotate by 180° (*Figures 15a & 15b*). One lance can repair the inside of snorkel A, while the other is doing the outside repair of snorkel B. When this is finished, the main base rotates, so snorkel A is repaired on the outside and snorkel B is repaired on the inside.

The advantage of placing the scraper and the gunning robot on the same service car is the time saved in handling. The complete operation of snorkel cleaning and inside/outside gunning can be performed in approximately 12 minutes (*Figure 16*).

For the inspection and documentation of the wear pattern it is possible to attach a camera to the robot (*Figure 17*). Instead of the gunning lance, a water-cooled camera is driven into the snorkel. A video can be made of the snorkel or the lower vessel area. The area of robot in the video can be exactly determined, using positioning encoders (*Figure 18*). The video can be stored and the wear can be documented. By this process the lifetime can be optimized. The inspected areas can be precisely repaired with the robot.

Salzgitter Flachstahl GmbH make use of a gunning installation manufactured by VELCO GmbH for the refractory maintenance process of the snorkels at their new RH plant (*Figure 19*). Two snorkel maintenance carriages are used for snorkel cleaning, and each is provided with a snorkel deskulling device. The platform of these carriages can be used for manual gunning too. The snorkel maintenance carriages move on rails and each one is dedicated to one RH plant.

The feeding of gunning material to the snorkel service carriage is carried out pneumatically by means of a pressure vessel machine and a pipe/hose system. The refilling of the gunning machine with material is done automatically and is dust-free. The recoupling of any hose is not required. In the first phase of construction the pressure vessel machine is filled by 'Big Bags'; in a subsequent phase this can be modified to silo filling (*Figure 20*).

The required compressed air, gunning water and electrical energy are fed to the snorkel service carriage via hose drums. A manual coupling is not required. The operator can either use automatic programmes or may control the maintenance process manually via a radio remote control. **MS**

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