Increased EAF availability with automatic refractory thickness scanner and gunning robot

The TERMINATOR is an automatic EAF refractory maintenance system comprising laser scanner and gunning robot which are linked by means of a central control unit that evaluates the measurement data and controls the gunning unit, automatically applying the appropriate amount of repair material at the required position. The savings achieved in terms of reduced maintenance time, repair material, hearth brick consumption and energy costs, considerably increase furnace productivity and decrease steel cost. The installation at Qatar Steel is described.

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Qatar Steel Company (formerly QASCO), based at Mesaieed, Qatar, was commissioned in March 1978 to produce steel reinforcing bars for domestic and regional demand. Qatar Steel consists of a Midrex direct reduction, EAF, continuous casting and rolling mill plants. The EAFs are charged principally with direct reduced iron (DRI), which is produced using Qatar’s abundant supply of natural gas, thus reducing dependence on imported scrap. This is essential due to the limited availability of local scrap and the high price of imported scrap.

Typically, the plant operates with 90-100% DRI, believed to be the highest in the world. This makes the furnace operating parameters very sensitive to any deviation in DRI quality. DRI production costs at Qatar Steel are relatively low due to the availability of cheap natural gas. In addition, Qatar Steel has succeeded in using DRI fines without additional processing, which has resulted in a further reduction in steel production costs.

It is important to note that EAFs operated with a high percentage of DRI and long, flat bath periods, have a much higher gunning and fettling mix consumption compared to typical scrap melting furnaces because the liquid bath is in contact with the refractories for approximately 90% of the total heat cycle – significantly longer than with a scrap-charged furnace.

Since its start up, the plant has made significant progress towards full use of all its production units, operating with the required quality and efficiency standards. By 1999 it had achieved a production figure of 645kt compared to its design capacity of 420kt from the initial two EAFs commissioned in 1977. A further two ultra high power (UHP) EAFs with eccentric bottom tapping (EBT) and tapping weights of 80t were added in 1998 and 2007. To further increase production, a fifth EBT EAF, with a 160t tap weight was commissioned in 2009. Currently, the plant comprises four 80t and one 160t capacity EAFs, four continuous casting machines, two long product rolling mills and two Midrex DRI modules. The plant currently has an annual liquid steel production of 1.2Mt/yr and a rolling mill capacity of 740kt/yr.

TERMINATOR INSTALLATION AT EAF 3

EAF availability is key to maximising production output, and in 2005 Qatar Steel installed the TERMINATOR automatic EAF refractory maintenance and laser contouring system (LCS) to optimise lining repair at EAF 3 (see Figure 1). EAF details are shown in Table 1. It comprises the following equipment:

- Two pressure vessel machines (ANKERJET) for gunning and fettling mixes, with a changeover system
- TERMINATOR gunning unit equipped with an air...
cooling system for the gunning head. The turret, with a horizontal boom and internal feed line, was specifically designed for the EAF 3 dimensions and available space. This unit is capable of applying gunning and fettling mixes to either a hot or cold furnace.

- An LCS to measure the residual refractory thickness of the furnace
- Separate arm with a water-cooled box containing the laser measuring head. The box is equipped with the necessary opening, closing and cleaning system required for heat and dust protection
- Central control unit with a visualisation screen. A computer converts the laser wear measurement data into operating instructions for the gunning unit
- Radio remote control and control box

All the gunning unit and LCS rotation, lifting and lowering movements are hydraulically powered. The mixes are conveyed from the pressure vessel machines through a hose and piping system to the gunning nozzle and all machines are equipped with safety installations. The gunning process can be conducted either via a portable radio remote control, enabling manual operation, or from the visualisation screen. This screen is used to initiate gunning after the wear profile of the furnace has been measured and to select the repair mix consumption, duration and degree of repair. The mix consumption and gunning duration can be documented through the central control unit or transferred to the Level 2 QS system.

High manoeuvrability enables the TERMINATOR to repair all parts of the EAF, including the banks, wall and cooling panels, as indicated in Table 2. Easy handling and the high degree of system flexibility ensure both rapid and precise lining repair.

The LCS measures the residual refractory thickness of the furnace and provides detailed scans of the residual refractory wall and wall contour maps (see Figures 2 & 3). The scanned profiles of the top layer and third layer are shown in Figures 2a and 2b. The residual refractory profile (black line) and specific wall thickness (boxed value) are also indicated.

The laser is installed on a separate arm beside the gunning lance. The measuring time is only 20s/scan and each complete scan takes only 30s including the positioning and removal time of the scanning arm. The measuring principle is via time of flight. The measuring range is 2-20m with a maximum operating temperature of...
1,700°C. As a result, it is very convenient to carry out the measurement once per shift. The central control unit and visualisation screen are the interface between the LCS and gunning robot. After scanning the furnace, the measured data (i.e., residual thickness of the refractory lining) is displayed on the screen in the furnace operation room. The operator highlights the areas requiring repair using a mouse. The repair mix consumption and gunning duration for the marked areas are automatically calculated and displayed. The operator can either accept the calculation and start the gunning process or, if the duration is too long, reduce the gunning time. The co-ordinates for the areas requiring repair are then automatically transmitted to the gunning unit. The TERMINATOR in operation is shown in Figure 4.

RESULTS
The TERMINATOR gunning robot system has been in operation at Qatar Steel for more than six years. Significant results achieved during this time through automatic EAF refractory maintenance include:

- The wall refractory lifetime increased from 293 to 878 heats per campaign after the TERMINATOR installation. Residual brick thickness at the end of the campaigns indicates a possible 1,000 heats per campaign.
- The wall refractory consumption has decreased from 0.96kg to 0.28kg/t of liquid steel after the TERMINATOR installation.
- As detailed in the contract, the cost of the hot and cold repair materials is fixed and is the responsibility of RHI.
- Furnace repair time has been reduced by four minutes per charge, reducing the tap-to-tap time per heat.

Additional benefits Due to the reduction in tap-to-tap time, other related parameters, including power and electrode consumption, have also reduced proportionately. Furthermore, there is no risk of a sudden liquid metal breakout since the lining thickness is monitored on a regular basis and the preventive gunning programme is applied – a safety benefit only possible with this type of equipment.

Given the long liquid steel residence time, as mentioned earlier, refractory performance at Qatar Steel is extremely good, even compared to the typically lower specific refractory consumption levels of scrap melting furnaces.

CONCLUSIONS
Since implementing the TERMINATOR fully automatic EAF maintenance system in 2005, multiple benefits resulting in increased EAF availability and productivity have been realised at Qatar Steel. Not only is the exact brick thickness in the EAF wall available to the operator at any time via the LCS measurement, but excessive use of repair materials can be avoided. Furthermore, repair time is reduced due to the high gunning rate of the TERMINATOR. Additionally, wall brick erosion can be uniformly maintained by programming the repair, and the hot heel can be scanned to compare LCS determined values with operator estimations, although the amount of slag in the furnace must be minimal.

Due to the encouraging results at EAF 3, a new fully automatic maintenance system was delivered in 2008 for EAF 4. This modified and improved version of the TERMINATOR has the additional capability of automatic temperature measurement and sampling through the EAF roof. This is achieved using a separate arm comprising two probes and will enable the EAF to be operated with closed doors. An additional TERMINATOR system was installed on the 160t EAF 5 in 2009.

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Fig 3 Wall contour map
Fig 4 Gunning robot in operation