

BSE-EAF – future-proof melting automated system for safe, reliable and efficient steelmaking

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Badische Stahl-Engineering GmbH (BSE) is one of the World leading engineering and consulting companies belonging to the Reinforcing Steel Europe B.V. Group (RSE-Group) with its own steel plant Badische Stahlwerke GmbH both located in Kehl/Germany.

Based on over 40 years of engineering and even longer operational experience and competence in the field of EAF-steelmaking, BSE developed its own EAF design with the focus on:

- Robust and reliable equipment
- Compact and easy to maintain components
- Design based on precise calculations and simulations of all parts of the equipment.
- Efficient power input, electrical and chemical
- High degree of automation
- Tools around the EAF for safe and reproducible activities during the EAF process and maintenance.
- Design to meet highest environmental standards

KEYWORDS: EAF STEELMAKING; EAF DESIGN; SAFETY AT EAF; AUTOMATIC FUNCTIONS AT EBT.

INTRODUCTION

Since several years EAF steelmaking is on the rise because CO₂ emissions are lower than production via the blast furnace and converter route especially when only scrap is used as charge material. A decision needs to be taken about which EAF technology fits best to the needs for the different kinds of products and raw materials used. For a scrap-charged EAF it is crucial that the dimensions fit the charge material, the electrical power input is adjusted to the shell diameter, and the chemical energy input is supplied correctly to the melt. Correct design leads to an efficient process with optimized performance figures.

All work around the EAF should be automated as much as possible or should be done by manipulators or robots to ensure work safety of the operators.

The following paper shows an example of where these features have been implemented together with the results after commissioning.

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through the slag door, slag door cleaning by oxygen as well as automatic temperature measurement/sampling during power-on.

The designed EAF for IDC expansion project features a net Tap-to-Tap-Time of less than 41 min. Details of the EAF time balance are shown in the following table.

Tab.2 - EAF Time balance.

| EAF TIME BALANCE: | | |
|----------------------------------|-----|------|
| power-on time | min | 29,3 |
| power-off times, total | min | 11 |
| • charging | min | 3 |
| • sampling | min | 0 |
| • tapping | min | 3 |
| • tap hole preparation | min | 1,5 |
| • electrode slipping/re-nippling | min | 1 |
| • furnace preparation | min | 0,5 |
| Unexpected delay | min | 2 |
| Net tap-to-tap, ttt | min | 40,3 |
| Net productivity / liquid steel | t/h | 224 |

To reach such low TTT-time with 2 bucket charge operations, the right set-up of available charging volume in the shell in combination with the set-up of scrap bucket volume is essential.

- rigid and stiff gantry body which houses the electrode- and roof-lifting system;
- bearing system consisting of 1x axial bearing and 2x radial bearings for accurate and fast movements;
- roof lifting system allows gantry swiveling without roof.

EAF Gantry Design

Another unique feature of the EAF is its gantry design. The gantry design features the following:

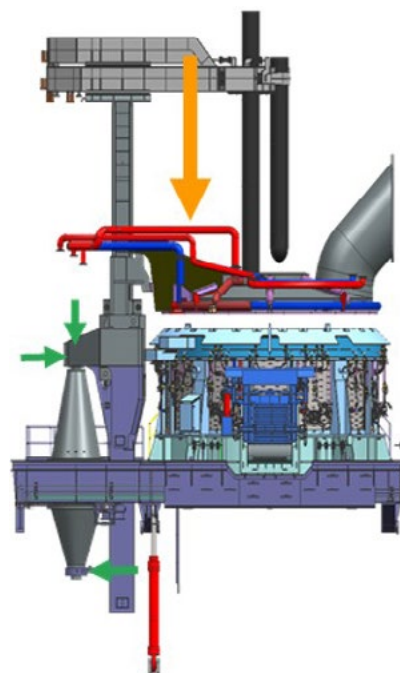


Fig.2 - EAF gantry with main loads.

Thanks to the unique bearing system design each bearing can be changed without dismantling of the gantry itself. Nevertheless, the bearings themselves are designed as slide bearings and feature a very long lifetime compared to usually used roller bearings for EAF gantries.

In figure 7 the main loads on the EAF gantry and the bearing system are visualized. The orange arrow represents

the total load from the equipment, and the green arrows show the loads on the 3 slide bearings of the system.

EAF Energy Input

The electrical energy input needs to match the size of the EAF shell to avoid high radiation to the side walls. In table 3 the transformer data is summarized.

Tab.3 - EAF transformer data.

| EAF TRANSFORMER DATA | | |
|--|-----|---------------|
| Transformer rating | MVA | 156 |
| Overload | % | - |
| Secondary voltage | V | 352-1137-1350 |
| Secondary current | kA | 79,2 |
| Electrode diameter | mm | 710 |
| Number of taps | - | 16 |
| Electrical power input, melting/refining up to | MW | 120 / 110 |

Following the transformer EAF high current system (HCS), secondary delta closure, high current cables and current conducting electrode arms need to be designed in accordance. A very important design tool is the use of BSE-FNM-simulation for the whole system. With the FNM-simulation [2] the design is optimized to achieve

highest possible "electrical symmetry" of the electrical power input during the operation of the EAF. One of the simulated parameters is the current density distribution in the hole system between transformer connections up to the electrode tips. The outcome of simulation for current density distribution is shown in figure 3.

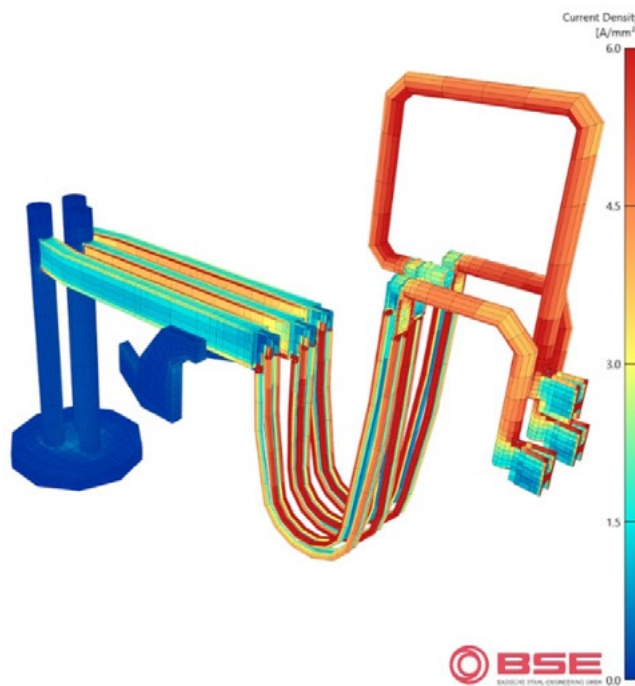


Fig.3 - FNM simulation of EAF-HCS (3D-view of current density).

The chosen design of the HCS can be summarized as follows:

- secondary delta closure in water-cooled copper pipe design with "current-loop" in Phase #2 for triangulation of the hole system;
- 3x 4 water-cooled high current cables;
- BSE-Copper/steel current conducting electrode arms in co-planar design with flanged electrode holders.

For chemical power input the BSE-VLB system was chosen.

The VLB-System is composed of the following units:

- 6x Tiltable VLB mounted in the shell side wall. Each unit with up to 6 MW thermal and up to 2200 Nm³/h oxygen lancing capacity;
- 1x EBT-VLB with up to 4 MW thermal and up to 2200 Nm³/h oxygen lancing capacity;
- 4x CarbJet-lances with carbon injection rate of up to 50 kg/min each;
- LM 2 with 2x oxygen and 1x carbon consumable lances through the slag door.

The layout of the VLB-system is shown in figure 5.

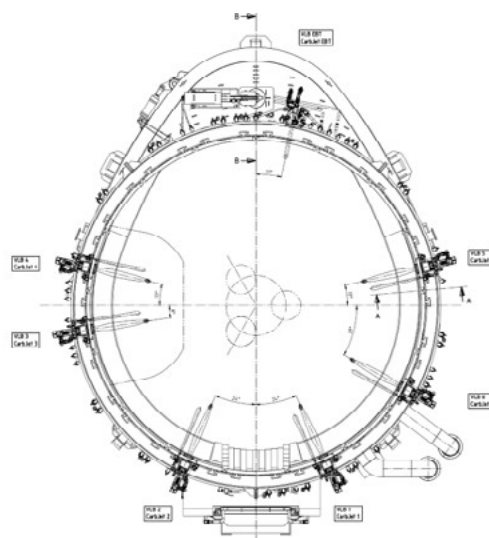


Fig.4 - VLB-system layout (top view).

Thanks to the tiltable design of the sidewall oxy/fuel-lance-burner, shown in figure 5 the thermal power can be up to 6 MW. Depending on the charge mix and operational requirements the control system enables the oper-

ator to use up to 40 MW chemical energy with this system. The control and power input are executed in automatic mode. Different, pre-programmed operational profiles can be selected depending on the requirements.

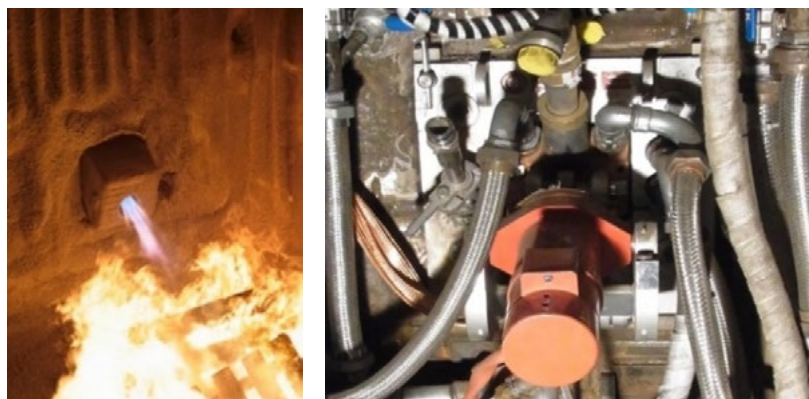


Fig.5 - Tiltable VLB mounted in EAF.

SAFETY TOOLS

For stable and consecutive EAF operation certain actions and activities need to be executed to ensure productivity and quality. Since these actions have to be executed mainly in danger areas, special safety equipment is required to ensure operator safety and ensure further improvement of overall process performance.

The following examples show technological develop-

ments in the field of automation and safety equipment around the EAF.

Manipulator for taphole cleaning (THM)

The Taphole Manipulator (THM) [3] is a very good example of how an established and proven operational standard can be used to develop a new technological solution for improving operational and working safety.



Fig.6 - THM entering taphole for cleaning.

In the past, tap hole breakthroughs frequently occurred caused by remaining slag in the tap hole channel before filled with tap hole refractory. To overcome these frequent breakthroughs with the related delays, the cleaning of the tapping channel with manual oxygen lance in combination with visual inspection before re-filling was set as a standard operation for each heat. As a result, these kinds of operation-delays became practically eliminated at BSW.

On the other hand, the established practice to prevent dangerous process conditions induced frequent manual operator actions in the area of the EBT-balcony panel with "unsafe working conditions".

Out of this fact, BSE, motivated by BSW, developed the THM for automatic cleaning and clearing of the taphole.

The features of the THM (patented solution) can be summarized as follows:

- oxygen radial nozzle for tap-hole channel and rim

cleaning at the tip of the mandrel;

- force control to avoid damage of the refractory taphole channel;
- max. piece to be removed from top of channel inside the EAF shell is equivalent to $\frac{1}{4}$ m³ of concrete (650 kg);
- stroke inside EAF-shell is approx. 400 to 500 mm, total stroke of device is 2'000 or 2'500 mm, depending on layout requirements;
- device can be used for taphole changing.

Figure 7 shows the THM during taphole cleaning at BSW EAF #2. The THM is mounted at the EAF tilting platform. The swiveling is executed by an electric drive, the stroke for clearing & cleaning by hydraulic cylinder. Heat exposed sections, like the lever, are water-cooled for reliable operation.

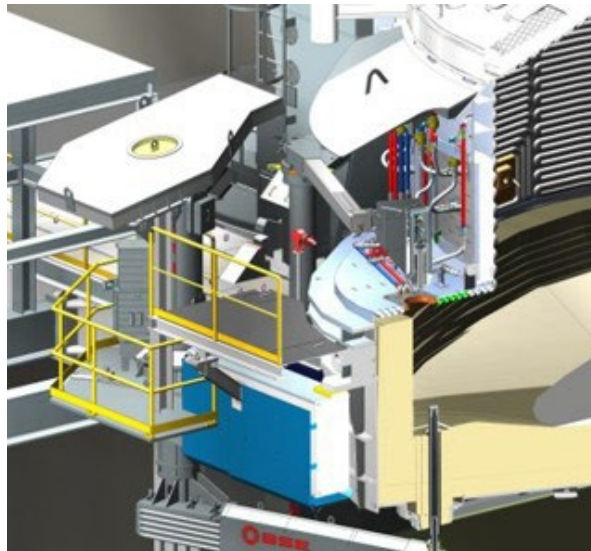


Fig.7 - EAF section view with EBT taphole filling.

Automated taphole filling @ EAF

As further part of EAF integrated automation for safety improvement the filling of the EBT tap hole is also already proven in daily operation of EAFs.

Figure 8 shows the EBT filling system in filling position in a

section view of an EAF. The filling hopper features a camera for observation of the taphole cleaning by THM and the filling itself. Figure 9 shows the process of cleaning the taphole and refilling.

EAF taphole monitoring

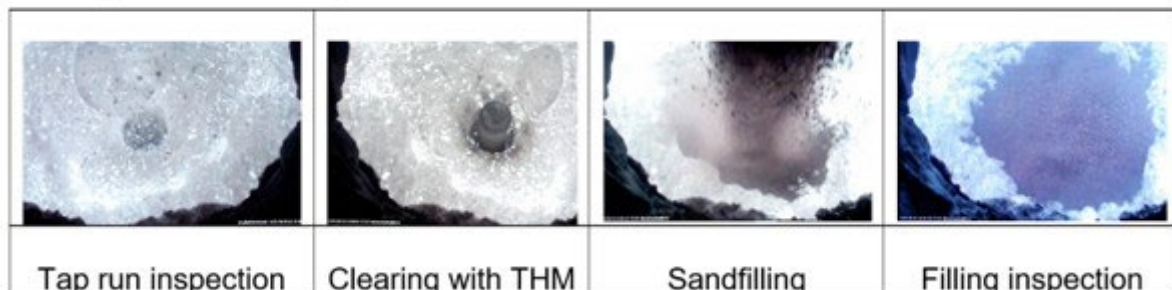


Fig.8 - EAF taphole monitoring showing different process steps.

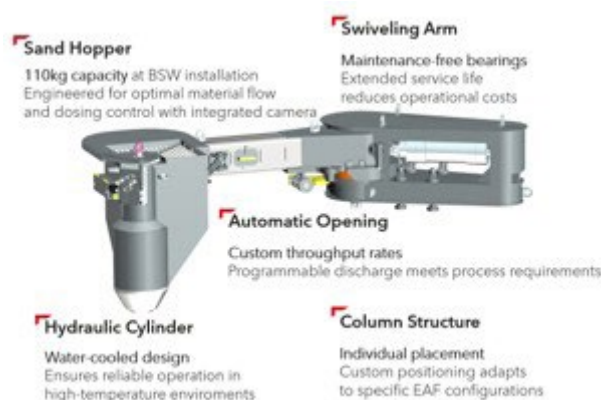


Fig.9 - EBT Sandman with main features.

The control of the system is integrated in the EAF Level 1 automation and therefore the residence of an operator in the EBT area for tap hole preparation is eliminated during normal EAF operation.

For supply of the filling hopper with the tap hole filling

refractory a standard pneumatic material conveying system is in use. According to the lifetime of the tap hole, the amount of material for filling is dosed.

EAF slag door with cleaning function

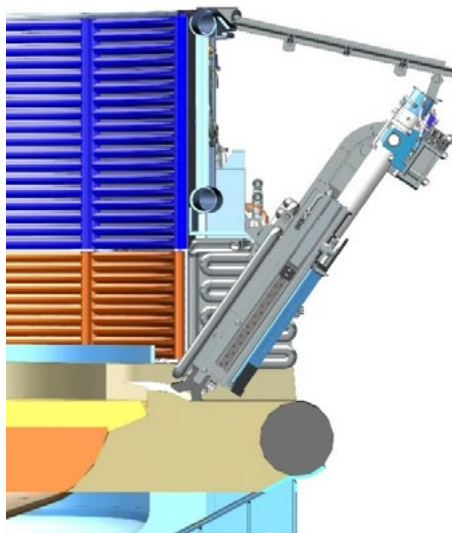


Fig.10 - Automatic slag door in charging position.

Another system for implementation can be the automatic slag door with the following features:

- reliable opening & closing of slag door during EAF process;

- tunnel & sill cleaning during operation;
- enabling of "closed door operation";
- safe & reliable operation;
- remote & "automatic" operation.



Fig.11 - BSE Doorman @ Özkan-EAF.

In figure 12 the slag door is shown in charging position. This position shall be used for complete melt down period and close the shell completely.

The BSE-DoorMan [4] is installed at Özkan EAF in Aliaga [5].

VISUAL INSPECTION @ EAF

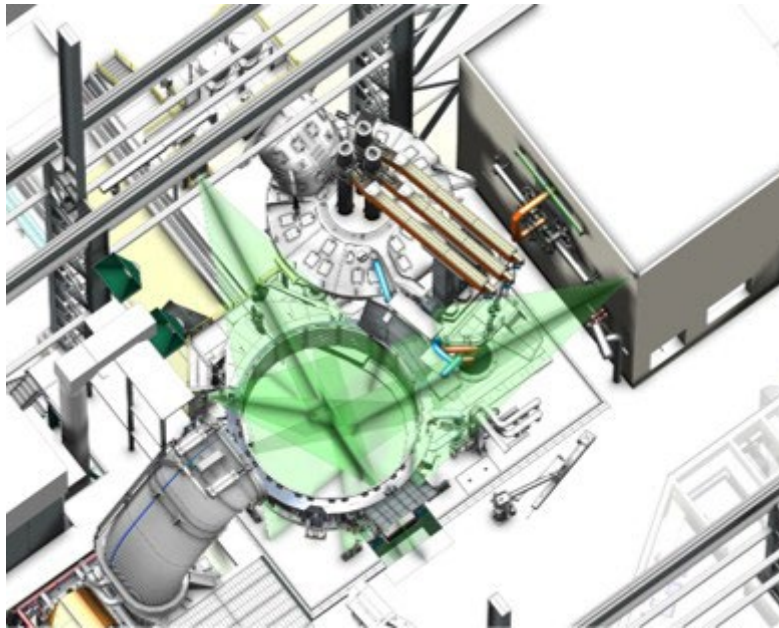


Fig.12 - Visual inspection with three cameras.

With three thermal cameras the complete circumferences of the EAF shell can be monitored. This visual information can give indications on skull build up, steel bath level, possible water leakages and several others. The operators can instantly judge the status of the EAF. With picture recognition tools this information is getting increasingly precise, and estimations of hot heel amount and possible water leakages can be given.

CONCLUSION

With smart design, automatic procedures through manipulators, visual inspection by special cameras, EAF operation can be optimized for maximum productivity at low cost and high safety level. More tools for further automation of the process will follow in the near future.

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