# PREFABRICATED SLAG DOOR SOLUTION – TO SOLVE A WELL KNOWN OBSTACLE TO INCREASE EAF PERFORMANCE

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## ABSTRACT

One of the bottlenecks for high performance of EAFs is extended refractory wear in the slag door area. This often limits the lifetime of the complete vessel. Problems are mainly related to grade selection, lining process/installation, and process conditions.

To overcome this issue Mayerton developed solutions with preassembled slag doors. The given example describes the implementation of such a slag door at National Steel (NASCO) in Saudi Arabia. NASCO is operating a split type EAF, which gives the opportunity to place such a preassembled slag door into the furnace.

Detailed engineering of the overall situation of the EAF (condition of furnace shell, installation equipment in steel plant, space for the block) is mandatory and has to be taken into account. For the correct choice of the refractory grade the knowledge of process parameters is essential as well. Specifics about the refractory detail engineering, grade selection, installation and performance results will be given in-depth in the paper.

## INTRODUCTION

Under the umbrella of Al Ittefaq Steel Products Company Ltd. (ISPC), National Steel Company Ltd. (NASCO) was established in Year 2004 with an annual capacity of 0.5 million metric tonnes (MT) of steel billets. Since then, NASCO has strategically enhanced its capacity to achieve 1.0 million MT production in 2013 through technical upgrades to maintain the quality and meet the increasing demand.

NASCO is a steel melt shop that produces steel billets for the ISPC group. They mainly produce construction steel grades through EAF-LF-CCM route. Steel scrap and direct reduced iron (DRI) are used. A state of the art, highly productive EAF with continuous DRI feeding system and advanced auxiliary equipment to ensure consistent production of quality steel is the primary facility. Novel is that an induction furnace (IF) with twenty ton capacity runs in combination with the EAF to increase overall output in a cost-effective manner. One ladle furnace (LF) is taking care for refining to ensure the desired quality is achieved. The steel is cast at a four strands billet continuous casting machine (CCM) with very high level of automation capable of producing billet sections of 130 mm to 180 mm[1]. The product mix spans from low-, medium- to high carbon grades. The official equipment manufacturer was Siemens-VAI.

The EAF is producing 24 – 28 heats per day. Due to the planned plant utilization and planned maintenance stops the lifetime is around 400 heats. After the end of the campaign the whole furnace is taken out with a heavy crane and replaced by a newly relined or repaired vessel which is directly taken into operational mode. One of the obstacles to extend the lifetime and to reduce the number of maintenance cycles is the high pre-wear at the slag door.

## RESULTS AND DISCUSSION

The EAF is lined in a common lining configuration. Above the three layers of permanent lining which are fired magnesia bricks a hearth ramming mass for the bottom and banks is placed. The side wall is lined with different MgO-C grades in respect of balanced lining, especially for the hot spot areas.

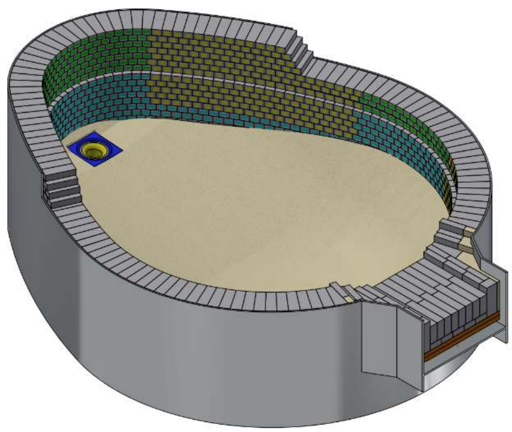


Fig 1. Lower shell of the EAF with refractory lining included.

The slag door area is the clearly defined weak point and is the main reason to take the furnace out of operation due to high pre-wear compared with the rest of the lining. Notable is the additional downtime for gunning the slag door area. It was decided to select a new refractory material together with a custom-fit engineered slag door solution.

Refractory selection:

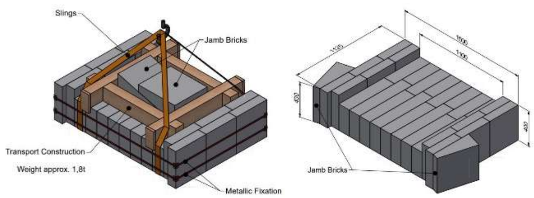
For choosing the best refractory material in an EAF, especially in the slag door area, several facts have to be taken into account: The atmospheric conditions as this area has a close contact to the normal atmosphere outside the furnace, thermal shocks and regular contact with slag. On the one hand high carbon content would increase resistance against slags but would on the other hand decrease oxidation resistance of the material. Antioxidants increase corrosion resistance but decrease hot strength of the refractory material.

The finally chosen refractory grade is based on the furnace operating conditions. The chosen material is based on high purity fused magnesia (FM 98) with a C/S ratio >2, a carbon content of around 15%, and a resin bond. For restrengthening the brick structure a well-known combination of metal powders was added to the brick (metallic Al and Si)[2,3], dense pressing of the bricks was chosen as the densifying method to prevent steel and slag infiltration into the brick's microstructure. For the final assembly of the slag door the single bricks were glued with a glue based on polyurethane with oxidic additions to give a maximum strength to the final piece part. The preassembly assures a perfect fit of every single brick in this critical area, avoiding steel or slag penetration into brick joints.

Slag door detail engineering:

There are some main facts to consider. Most importantly, the upper part must be separably from the lower part of the kiln shell. This gives the opportunity to set a prefab solution into the furnace from above. Furnace steel shells which have been in operation for several years normally show thermos-mechanical deformation. This deformation has to be considered for the detailed design engineering.

NASCO runs an EAF split type vessel which gives the opportunity to set a preassembled slag door solution in one piece with a crane into the furnace during maintenance or refractory rebuilt. Figure 2a shows the slag door refractory design with the handling slings. The jamb bricks (Fig. 2b) will be settled separately after setting the block to close the gap to the wall lining (Fig. 1).




(a) (b)

Fig. 2. (a) Prefab slag door with lifting slings, (b) with jamb bricks set in place.

Before setting the prefab slag door into its final place the flatness of the surface was checked (Figure 3 a). To avoid steel and slag penetration in the horizontal gap between standard lining and the prefab block it was decided to use a mortar between the seating pad and the prefab block (Figure 3 b).

(a) (b)

Fig. 3 (a) check the flatness, (b) mortar patching.

Figure 4 depicts the prefab block manipulation on the lifting device before setting. It has to be noticed that the mortar layer brings an additional benefit for the fine adjustment of the block due to the reduced friction.

Fig. 4. Setting in place the preassembled slag door block.

Essential for the stable mechanical fixation are large vertical pilar bricks, which are set left and right of the slag door block (Figure 5 a and b). The necessary tolerances/gap between the pilar bricks, jam bricks and upper shell are essential for mounting the upper shell and to compensate the brick elongation during furnace operation (Figure 6). The gap between bricks and water cooled panels was closed with conventional patching mortar.

(a) (b)

Fig. 5. after setting the upper shell (a) left and (b) right pillar bricks were set as connection to the wall lining.

Fig. 6. Prefab slag door solution after mounting the upper shell.

The complete newly relined furnace with the prefab slag door went into operation directly after completion of the maintenance on October 12$^{th}$ 2022. The EAF campaign duration was scheduled for exactly 3 weeks with high plant utilization with very limited time for gunning. Figure 7 gives an impression about the furnace refractory after 20 heats while Figure 8 shows the status at 338 heats after gunning.

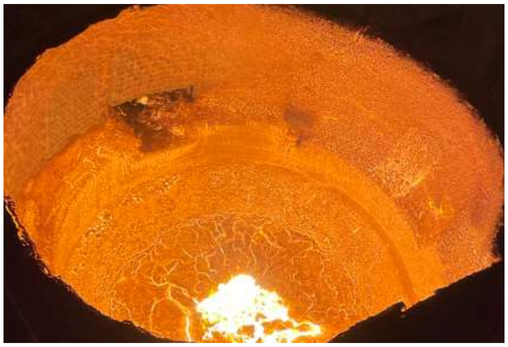


Fig. 7. EAF after 20 heats.


Fig. 8. EAF after 338 heats.

The furnace was taken out of operation after 422 heats. The expectation of achievable lifetime, maintenance service activities and residual lining thickness was more than fulfilled. Figure 9 shows the lower shell area after dismantling from the upper shell with the slag door directly before wrecking. The remaining thickness of the prefab slag door would allow additional approximately >100 heats. This positive result with the residual thickness is the ignition to modify the whole lining configuration to extend the planned EAF operation.


Fig. 9. After demounting the upper shell – lower shell with slag door area.

In a further trial the target of 450 heats has been reached without any problems in the slag door area.

## CONCLUSION

Besides safe handling and fast mounting the prefabricated slag door solution showed its main benefit – debottlenecking a critical area of refractory service life and therefor extend the furnace operation with reduced downtime for gunning which led to higher plant productivity and reduced OPEX. Nevertheless, the right choice of the refractory material was essential as well.


## ACKNOWLEDGEMENT

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