MGO-C REFRACTORY SELECTION AND EVALUATION FOR STEELMAKING VESSELS

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Abstract

The challenge for refractory material producers and consumers is to find the optimum solution between the quality and cost of the product with its value in use.

Magnesia-Carbon (MgO-C) refractories in Steelmaking vessels play an important part to reach continuous improvement targets. It will remain a focus area to increase campaign length of vessels and reduce the cost per ton liquid steel produced.

Improvements of 20% can be achieved by using different quality MgO-C refractories.

1. Introduction

The Vanderbijlpark Works of ArcelorMittal, South Africa, consists of the following:

- Integrated route with 3x 170t Basic Oxygen Furnaces (BOF), 2x Ladle Furnaces (LF), 1x RH and 2x Twin strand slab casters with capacity of 2.9 mtpa.
- Minimill route with 3x 150t Electric Arc Furnace (EAF), 2x LF’s, 1x Vacuum Arc Degasser and 1x Twin strand slab caster with capacity of 1.4 mtpa.

The 3 BOF’s are bottleneck units in the Oxygen Steelmaking Route and various strategies have been implemented to manage the cost, availability and throughput of this route. These include:

- Extend campaign length with slag splashing
- Maximum utilization of bottom stirring

The selection and properties of the MgO-C refractories used with these different philosophies and varying operating conditions determine both the length of the campaign achieved and the cost of the lining.
2. **Background**

The following operational conditions affect lining wear:\(^1\):

- Slag chemistry
  - Basicity
  - MgO content
  - FeO levels
- Size of scrap charged
- End point temperature
- Reblows
- Production Rates (i.e. heats per vessel per day)
- Holding time (blow end to tap start)
- Hot metal quality (limits total mass of fluxes that can be charged)

In order to optimally utilize or consume the refractories, the following maintenance or repair techniques are utilized with the impact on performance indicated in Fig. 1:

- Gunning of localized high wear areas
- Slag coating: by keeping some slag in the vessel, adding MgO containing material and tilting the furnace over the tap floor and charge pad areas.
- Slag splashing by blowing high pressure N\(_2\) via the top blown lance\(^2\) and coating the complete surface with a slag layer.

The result achieved with such methods is determined by the time available and the frequency of these activities. In the case of gunning, the durability can be extended by using improved raw material and binder systems and for slag splashing, low oxide- and higher MgO levels in the slag.

The drive to improve efficiencies and reduce costs resulted in a change of strategy. Slag splashing was stopped and the focus changed to ensure bottom stirring availability and efficiency for the full duration of the campaign. This leads to lower campaign lengths as indicated in Fig. 1.

The higher refractory cost is countered by savings as a result of lower oxygen levels in the steel and slag. Higher quality MgO-C bricks are required in order to improve campaign lengths with little or no refractory maintenance (i.e. gunning and splashing).
3. Lining Development

The different areas and wear mechanisms are displayed in Fig. 2 and Table 1\(^1\).

**Fig 2 : BOF- wear areas**

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Table 1: Furnace Area Wear Conditions

<table>
<thead>
<tr>
<th>Furnace Area</th>
<th>Wear Conditions</th>
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<tbody>
<tr>
<td>Cone</td>
<td>Oxidizing atmosphere</td>
</tr>
<tr>
<td></td>
<td>Mechanical abuse</td>
</tr>
<tr>
<td></td>
<td>High temperature</td>
</tr>
<tr>
<td>Trunnions</td>
<td>Oxidizing atmosphere</td>
</tr>
<tr>
<td></td>
<td>Slag corrosion</td>
</tr>
<tr>
<td></td>
<td>Slag and metal erosion</td>
</tr>
<tr>
<td>Charge Pad</td>
<td>Mechanical impact</td>
</tr>
<tr>
<td></td>
<td>Abrasion from scrap and hot metal</td>
</tr>
<tr>
<td>Tap Pad</td>
<td>Slag erosion</td>
</tr>
<tr>
<td></td>
<td>High temperature</td>
</tr>
<tr>
<td></td>
<td>Mechanical erosion</td>
</tr>
</tbody>
</table>

The Refractory performance can be improved by:

- Design changes in:
  - knuckle area
  - cone area
  - use of steel cladding
- Zoning of the furnace according to the different wear mechanisms and material qualities.

4. Evaluation Process

The following tests were conducted:

- Rotor slag test: 300g slag per cycle, 10 cycles of 20 minutes each after melting of slag
- Oxidation resistance: 50 x 50 x 75mm sample heated in air at 900°C or 1400°C for 8 hrs.
- 2 step rotor slag test: do 10 cycles, cool down and repeat.

4.1 Rotor slag test

Typical BOF slag was used to compare resistance to chemical attack (Fig. 3). The depth of slag penetration (Fig 4) is important as this will increase the wear rate during operation. The thermal expansion properties are different compared to the virgin material which will lead to cracking of this layer during thermal cycling.
4.2 Oxidation Resistance

Oxidation of fixed carbon and the binder system occurs during preheat and operation. The white decarburized layer can be seen on the bricks during the demolition process.

Both the depth of the oxidized layer and the condition of the oxidized layer are compared (Fig 5)
4.3 Two step rotor slag test

Both the global economic slump and normal throughput requirement affect plant stability. This implies that the golden rule for good refractory performance - “keep it hot” is not always adhered to. Depending on whether 2 or 3 furnaces are in operation and with throughput variations from 20 to 54 heats per day, a furnace can be used for 6 to 27 heats per day. To reduce this effect 1 or 2 furnaces can be stopped from 8 hrs to a few days at a time. Depending on the production schedule or maintenance requirement the spare furnace can be on hot or cold standby.
Table 2: BOF Operating parameters

<table>
<thead>
<tr>
<th></th>
<th>2 Furnace Operation</th>
<th>3 Furnace Operation</th>
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<tbody>
<tr>
<td></td>
<td>BOF 1</td>
<td>BOF 2</td>
</tr>
<tr>
<td>Number Of Casts</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>End Point C avg</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>End Point O₂ avg</td>
<td>536</td>
<td>532</td>
</tr>
<tr>
<td>Slag TFe avg</td>
<td>15.4</td>
<td>15.5</td>
</tr>
<tr>
<td>Slag MgO avg</td>
<td>8.2</td>
<td>8.7</td>
</tr>
<tr>
<td>End Point Temperature avg</td>
<td>1672</td>
<td>1669</td>
</tr>
<tr>
<td>Blow End To Tap Duration avg</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Tap To Tap avg</td>
<td>57</td>
<td>85</td>
</tr>
<tr>
<td>Basicity avg</td>
<td>3.2</td>
<td>3.0</td>
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<tr>
<td>Co-Product avg</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Percentage reblow</td>
<td>5.6</td>
<td>29.4</td>
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</table>

To simulate this impact the 2 step rotor test was conducted. The result in wear and condition of the samples after the 2\textsuperscript{nd} test is displayed in Fig 3.

5. Plant trial

Furnace layout
To evaluate the supplier - material combinations in a reliable trial, it was decided to do panel tests in 1 furnace rather than to install complete linings in different furnaces.

Fig 7. BOF Trial Zoning
The life of the furnace will be determined by the highest wear area (material with the lowest performance) and the campaign may end prematurely as a result of this. The advantage however is that variations in operational parameters between furnaces are excluded.

With this layout 2 qualities can be compared to a reference (and each other) on the trunnion and tap floor area (the highest wear areas during the planning stage of the trial).

6. Results

Wear profiles can be measured with the laser scanner during operation and results are displayed in Fig 8 to 11 for the different areas. Extensive gunning maintenance was started on the high wear areas after 1,000 heats and this is reflected in the data.

**Fig 8 : Laser scan profile at heat 1,081**
Fig 9: Wear rate Tapfloor (mm/heat)

Fig 10: Wear rate Trunnion East (mm/heat)
Table 3 indicates the expected life of the furnace based on the remaining thickness and the wear rate since the previous scan. It can be seen that trial quality B performs better than both the reference and quality C, while quality C compares well with the reference.

**Table 3 : Campaign Forecast**

Min Remaining Thickness (mm) = 50

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<tr>
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<tr>
<td>753</td>
<td>1,914</td>
<td>2,076</td>
<td>2,061</td>
<td>3,086</td>
<td>1,628</td>
<td>2,039</td>
<td>1,361</td>
<td>1,448</td>
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<tr>
<td>901</td>
<td>2,356</td>
<td>2,398</td>
<td>2,559</td>
<td>3,375</td>
<td>1,747</td>
<td>2,099</td>
<td>1,504</td>
<td>1,365</td>
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<tr>
<td>1,081</td>
<td>2,045</td>
<td>2,144</td>
<td>2,331</td>
<td>2,950</td>
<td>2,616</td>
<td>3,066</td>
<td>1,547</td>
<td>1,486</td>
</tr>
</tbody>
</table>

**Improvement vs R per area at 901 heats before gunning started**

- Tap breast: 101.8%
- East Trunnion: 131.9%
- West Trunnion: 120.2%
- Trunnion W : C: 90.8%

7. **Conclusion**

Both the Pilot Plant tests and Plant trials indicated a difference in performance of supplier - quality combinations.
It is possible to achieve up to 20% improvement in the life of the BOF at Vanderbijlpark by using different qualities MgO-C material.

With changing market conditions the impact of availability and opportunity costs will have an effect on the selection of Refractory materials in the Steelmaking Vessels.

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Reference

2. Everlasting BOF linings at LTV steel, R.O. Russel a.o. LTV steel company, Independence, Ohio – USA P220-225

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