Injection of BOF slag through Blast Furnace Tuyeres—Trials in an Experimental Blast Furnace

Peter Sikström*
Lena Sundqvist Ökvist**
Jan-Olov Wikström*

* MEFOS
Box 812
Se-971 25 Luleå
Sweden
Tel +46 920 201 900
Fax +46 920 255 832
psi@mefos.se
jow@mefos.se

** SSAB Tunnplåt AB
Se-971 88 Luleå
Sweden
Tel +46 920 92 000
lena.sundqvist@ssab.com

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INTRODUCTION

Background

The favorable production results achieved with blast furnaces in Sweden are mainly attributable to the use of high-quality olivine pellets (MPBO and KPBO) produced by LKAB (Swedish pellet producer) in Malmberget and Kiruna [1]. The pellets have, in general, a stable reduction behavior, a low gangue content and a very narrow softening and melting interval. Very high productivity, a low slag volume and a low consumption of reducing agents have been achieved when using 100% olivine pellets [1].

Focused on attaining even better blast-furnace performance, a new type of fluxed pellet with an even lower gangue content has been under development. The metallurgical properties of this pellet type are quite good, such as high reducibility and a narrow softening and melting temperature interval [2]. However, industrial trials in the early nineties using this type of fluxed pellet have not revealed the expected improvements in blast-furnace performance. The slag volume in the trials was very low, approximately 120 kg/tonne of hot metal (THM). One cause of this has been theoretically attributed to a problematic slag-formation process in the furnace by Professor Ma [3]. The fluxed pellet itself has an early melting slag, but when it is charged together with basic fluxes, an excessive basic slag can form in the cohesive zone where the top-charged basic fluxes partly dissolve into the primary pellet slag. The newly formed slag can have a very high melting point and a low fluidity which can even result in re-solidification of the slag. The melting properties of the FeO-rich slag become even poorer when it is further reduced and the FeO content decreases. As a result, the permeability of the cohesive zone and of the bosh region is decreased. A proposal to inject basic fluxes via the tuyeres instead of charging from the top has been made to enhance the slag-formation process at very low slag volumes [3].
When the fluxed pellets (with a basicity BB=1 (BB= wt%CaO/wt%SiO2)) are used, the top-charged fluxes that are supposed to neutralize the coke and coal ash dissolve in the early melting bosh slag and increase the basicity as well as its melting point. The local excessive basicity is even higher than average because of an uneven distribution of the fluxes charged into the blast furnace. If the fluxes are tuyere injected, the excessive basicity of the bosh slag is avoided and the basicity of tuyere slag is increased considerably from BB=0.05. In Figure 1 the basicity of primary slag, bosh slag, tuyere slag and final slag is compared for self-fluxed pellets with and without injection of BOF (Basic Oxygen Furnace) slag. The primary slag is formed from the gangue content in the pellets. The bosh slag is considered to be formed by the primary slag, all additives and fluxes and some ash from the coke that is consumed. The ash released in the raceway when coal and coke are combusted forms the tuyere slag. The tuyere slag contains the constituents of fluxes, if they are injected. The bosh slag and tuyere slag are mixed and after some additional reduction of the mixed slag the final slag is formed. As can be seen, the excessive basicity of the bosh slag can be avoided by the injection of fluxes.

In the research program of Jernkontoret (The Swedish Steelmakers’ Association), the project “Injection of fluxes into the blast furnace” was started and the effect of basic fluxes on slag formation in the blast furnace was studied. Laboratory tests of the softening and melting properties of different types of LKAB pellets, with and without additional fluxes, corresponding to bosh slag formation were carried out. Melting-point measurements of coke and coal ashes, with and without the addition of different basic fluxes, corresponding to the tuyere slag, were also performed. Among the fluxes tested (BOF slag, burnt lime, burnt dolomite), BOF slag had the best effect in terms of decreased melting temperature and softening and melting temperature interval for all injection levels tested [4]. In Figure 2 the effect on the melting point when adding BOF slag up to a certain basicity of the tuyere slag is shown. Chemical analyses, melting-point measurements and morphological studies were also carried out on samples from the laboratory softening and melting tests as well as on samples from the LKAB Experimental Blast Furnace at MEFOS. The test results showed that the additional basic fluxes could improve softening and melting properties of olivine pellets to a certain extent, but could significantly deteriorate the melting properties of fluxed pellets. The results indicate that interaction between pellet and fluxes occurs at local spots when the softening and melting begin and may cause variations in slag composition and slag properties at different levels in the blast furnace as well as at different radial positions, especially with an uneven distribution of fluxes. The basic fluxes probably caused the deteriorated melting properties of the fluxed pellet by formation of a high-basicity slag. The negative effect on slag formation caused by top-charged fluxes can be avoided by injecting the fluxes through the tuyeres. Injection of fluxes improves the melting properties of the tuyere slag considerably [4][5][6].

\[ \text{Bells Ratio} = \frac{\text{wt}\%\text{CaO} + 0.69 \times \text{wt}\%\text{MgO}}{0.93 \times \text{wt}\%\text{SiO}_2 + 0.18 \times \text{wt}\%\text{Al}_2\text{O}_3} \] (1)
THE EXPERIMENTAL BLAST FURNACE

A simplified layout of the Experimental Blast Furnace is shown in Figure 3. It has a working volume of 8.2 m$^3$ and a hearth diameter of 1.2 m. There are three tuyeres placed at 120 degree intervals. As great effort has been made to keep heat loss at a minimum, insulating refractories were chosen. Only the bosh area and the tuyeres are water-cooled. The blast is normally preheated to 1200°C in a new type of pebble heater.

The Experimental Blast Furnace is equipped with a bell-type top. A moveable armour is used for the burden distribution control. Two mechanical stock rods monitor the burden descent and control the charging of the furnace. The furnace has one tap hole which is opened with a drill and closed with a mud gun. The hot metal and slag are tapped into a ladle. Probes for temperature measurements, gas analysis and solid sampling over the blast furnace diameter are installed at three different levels. To make dissection and repair easy, the hearth is detachable and can be separated from the furnace.

Operating the Experimental Blast Furnace

The blast furnace is operated in campaigns of 4 - 10 weeks at a productivity ranging from 3.2 to 3.8 t/m$^3$/day. The normal tap-to-tap time is 60 minutes and normal tapping duration 5 - 15 minutes. Process data are logged continuously and stored in a database. The data are transferred at regular intervals to another database where reports and trend charts are generated and process calculations are carried out.

The Experimental Blast Furnace is a very sensitive tool for detecting differences in properties of different ferrous burden. The response time is much shorter for the experimental furnace compared to a commercial furnace.

Injection System

The Experimental Blast Furnace is equipped with a lock-hopper coal-injection system. Below the injection vessel a cylindrical fluidizing chamber is fitted. That chamber fluidizes the coal and supplies the pipes with coal for transport to the blast furnace. There is one transport line for each tuyere.

For the BOF slag injection a separate vessel is connected to the fluidization chamber, with a volumetric screw feeder. The slag-forming material mixes together with the coal powder in the fluidization chamber.

TRIAL USING THE EXPERIMENTAL BF

During a two-week period in November 2000, an experiment with simultaneous injection of pulverized coal and BOF slag was carried out. Before this trial, two shorter experiments with injection of fluxes into the experimental BF had been performed. The results of these two earlier experiments were very promising, but the effects on the process in terms of process stability, hot metal and slag composition, alkali refining and sulphur refining had to be further studied. To evaluate these effects, the later two-week test was made, financed by Jernkontoret, LKAB and SSAB. The results from the injection trial performed are discussed below.
Periods

The trial was divided into five periods, the first being a “reference” period, that is without any BOF-slag injection. Periods 1 and 2 were transition periods, to carefully, step by step, reduce the slag volume. Periods 3 and 4 were the substantial test periods. The original test plan is shown in Table I.

<table>
<thead>
<tr>
<th>Period</th>
<th>Duration</th>
<th>Slag volume</th>
<th>Pellets type</th>
<th>PCI</th>
<th>BOF slag inj.</th>
<th>Top charged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>48</td>
<td>140</td>
<td>70/30</td>
<td>100</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>Period 1</td>
<td>72</td>
<td>140</td>
<td>70/30</td>
<td>100</td>
<td>25</td>
<td>Yes</td>
</tr>
<tr>
<td>Period 2</td>
<td>24</td>
<td>125</td>
<td>70/30</td>
<td>100</td>
<td>25</td>
<td>Yes</td>
</tr>
<tr>
<td>Period 3</td>
<td>96</td>
<td>115</td>
<td>70/30</td>
<td>100</td>
<td>25</td>
<td>Yes</td>
</tr>
<tr>
<td>Period 4</td>
<td>120</td>
<td>100</td>
<td>100/0</td>
<td>100</td>
<td>36</td>
<td>No</td>
</tr>
</tbody>
</table>

Raw Materials

The trial was carried out with a mixture of 70 % Pellet A and 30 % Pellet B, except for the last period, which was operated with 100 % Pellet A. The reason for mixing two types of pellets was to achieve a suitable slag composition. The last period was operated with Pellet A as the only ferrous material in order to reach an acceptable slag basicity when no fluxes were charged through the top.

The coke was crushed and sieved to a fraction of 15-30 mm, i.e. standard coke for the Experimental Blast Furnace. The top-charged slag-forming materials were limestone, quartzite and BOF slag. The particle size of the slag formers was 9-15 mm, and the injected BOF slag particle size was slightly smaller than that of the pulverized coal, 80 % of which is smaller than 100 μm. Pulverized BOF slag was selected as an injection material for its slag-formation properties and the fact that it is easy to handle in a pneumatic system.

RESULTS

The operational results were excellent, and the trial was performed without any major disturbances. Burden descent and permeability, as well as all other process parameters, were smooth and stable. The results of calculated mass balances for each period are provided in Table III.

Reductants

The consumption rate of reductants in total decreased by 11 kg/tHM in the last period compared to the reference period. The change was primarily in the coke rate. The coal injection was kept constant as much as possible. It was mainly the fact that it was possible to operate the furnace with a lower and more stable silicon level in the hot metal as well as a lower slag volume that led to the reduced reductant rate.
Table III. Results of calculated mass balance for each period

<table>
<thead>
<tr>
<th></th>
<th>Hours total</th>
<th>Prod. tonne/h</th>
<th>Slag vol. kg/tHM</th>
<th>Coke kg/tHM</th>
<th>Coal inject kg/tHM</th>
<th>Fuel-rate kg/tHM</th>
<th>BOF slag inj kg/tHM</th>
<th>Top-charged slag formers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>34</td>
<td>1.33</td>
<td>136</td>
<td>439</td>
<td>98</td>
<td>537</td>
<td>0.0</td>
<td>Limestone, Quartzite, BOF slag</td>
</tr>
<tr>
<td>Period 1</td>
<td>57</td>
<td>1.39</td>
<td>138</td>
<td>444</td>
<td>93</td>
<td>538</td>
<td>23.3</td>
<td>Limestone, Quartzite, BOF slag</td>
</tr>
<tr>
<td>Period 2</td>
<td>20</td>
<td>1.38</td>
<td>129</td>
<td>446</td>
<td>99</td>
<td>545</td>
<td>24.3</td>
<td>Limestone, Quartzite, BOF slag</td>
</tr>
<tr>
<td>Period 3</td>
<td>92</td>
<td>1.43</td>
<td>110</td>
<td>440</td>
<td>93</td>
<td>532</td>
<td>24.3</td>
<td>Limestone, Quartzite, BOF slag</td>
</tr>
<tr>
<td>Period 4</td>
<td>110</td>
<td>1.42</td>
<td>101</td>
<td>428</td>
<td>98</td>
<td>526</td>
<td>36.9</td>
<td>None</td>
</tr>
</tbody>
</table>

**Tuyere and Top-Gas Parameters**

The blast amount, as well as the flame temperature, was kept relatively constant during the whole trial (see Table IV). The gas utilization, $\eta_{CO}$, was similar for all periods, approximately 47%, which is normal for this kind of burden in the Experimental Blast Furnace as shown in Table IV.

Table IV. Tuyere and top-gas parameters for each period

<table>
<thead>
<tr>
<th></th>
<th>Tuyere parameters</th>
<th>Top-gas parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blast Temp °C</td>
<td>Flame Temp °C</td>
</tr>
<tr>
<td>Reference</td>
<td>1129</td>
<td>2158</td>
</tr>
<tr>
<td>Period 1</td>
<td>1129</td>
<td>2164</td>
</tr>
<tr>
<td>Period 2</td>
<td>1129</td>
<td>2148</td>
</tr>
<tr>
<td>Period 3</td>
<td>1129</td>
<td>2147</td>
</tr>
<tr>
<td>Period 4</td>
<td>1130</td>
<td>2157</td>
</tr>
</tbody>
</table>

**Hot-Metal Quality**

The trial showed that hot metal silicon content significantly decreased while the carbon content stayed at a relatively constant level. Period 4, which was operated with the BOF-slag injection as the only added slag former, had lower Si and C contents at the end of the period. The reason for this was a conscious decrease in the fuel rate to see if any problems would arise in operating at a reduced heat level in the furnace. No problems occurred.

During period 4 the standard deviation in hot metal silicon stabilized on a lower level. This indicates that the blast-furnace process was stable. The hot metal analysis results for each period are presented in Table V. The silicon content in relation to hot metal temperature is considerably higher during the reference period compared to the periods with injection of fluxes. The silicon contents for periods 3 and 4 were 0.3 % lower than for the reference period, as illustrated in Figure 5.

Table V. Average hot-metal component concentrations for each trial period

| Trial period | Temp °C | C wt-% | Si wt-% | Si stdv | C/Si | Mn wt-% | P wt-% | S wt-% | (S)/[S] %/%
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>1416</td>
<td>4.12</td>
<td>1.28</td>
<td>0.31</td>
<td>3.17</td>
<td>0.16</td>
<td>0.044</td>
<td>0.120</td>
<td>11.5</td>
</tr>
<tr>
<td>Period 1</td>
<td>1418</td>
<td>4.31</td>
<td>1.09</td>
<td>0.27</td>
<td>4.01</td>
<td>0.17</td>
<td>0.043</td>
<td>0.095</td>
<td>12.5</td>
</tr>
<tr>
<td>Period 2</td>
<td>1431</td>
<td>4.51</td>
<td>1.16</td>
<td>0.25</td>
<td>3.91</td>
<td>0.16</td>
<td>0.040</td>
<td>0.057</td>
<td>26.0</td>
</tr>
<tr>
<td>Period 3</td>
<td>1426</td>
<td>4.37</td>
<td>1.04</td>
<td>0.19</td>
<td>4.20</td>
<td>0.13</td>
<td>0.037</td>
<td>0.078</td>
<td>21.1</td>
</tr>
<tr>
<td>Period 4</td>
<td>1423</td>
<td>4.24</td>
<td>1.00</td>
<td>0.18</td>
<td>4.09</td>
<td>0.14</td>
<td>0.035</td>
<td>0.082</td>
<td>22.8</td>
</tr>
</tbody>
</table>

Figure 5. Silicon in relation to hot-metal temperature
Slag

During the trial the slag volume decreased from 140 to 100 kg/tHM. The average slag component concentrations for each period are shown in Table VI.

The low slag volume, and accordingly higher slag Al₂O₃ content, did not cause any problems regarding the slag viscosity.

The change in slag composition is shown by the arrow in Figure 6. As can be deduced from the phase diagram, a further increase in Al₂O₃ or CaO content could cause a problem by increasing the melting temperature.

Alkalis

The absorption of alkalis by the slag was also slightly improved in this trial, as shown in Figure 8. No problems associated with the accumulation of alkalis were noted in spite of the fact that the slag basicity was higher at the end of the trial.

Pellet included in material samples taken with the inclined probe at the upper level of the cohesive zone was studied by SEM analysis. Condensed slag phases were found on the pellet surface as well as in areas of high porosity. One example of this is shown in Figure 7. The slag quite often contained oxides with high contents of K in combination with Si and Al. These oxides were found in all samples studied from the reference period as well as from the test periods.

Table VI. Average slag component concentrations for each trial period

<table>
<thead>
<tr>
<th>Period</th>
<th>CaO wt-%</th>
<th>SiO₂ wt-%</th>
<th>Al₂O₃ wt-%</th>
<th>MgO wt-%</th>
<th>K₂O wt-%</th>
<th>K₂O-yield</th>
<th>S wt-%</th>
<th>S-distr. [%]</th>
<th>MnO wt-%</th>
<th>Basicity CaO/SiO₂</th>
<th>Bells (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>32.1</td>
<td>38.6</td>
<td>14.7</td>
<td>11.6</td>
<td>0.59</td>
<td>0.64</td>
<td>1.28</td>
<td>11.5</td>
<td>0.42</td>
<td>0.83</td>
<td>1.04</td>
</tr>
<tr>
<td>Period 1</td>
<td>34.1</td>
<td>37.5</td>
<td>14.6</td>
<td>11.5</td>
<td>0.43</td>
<td>0.50</td>
<td>1.31</td>
<td>12.5</td>
<td>0.34</td>
<td>0.91</td>
<td>1.12</td>
</tr>
<tr>
<td>Period 2</td>
<td>34.3</td>
<td>34.0</td>
<td>16.0</td>
<td>11.7</td>
<td>0.34</td>
<td>0.41</td>
<td>1.63</td>
<td>26.0</td>
<td>0.22</td>
<td>1.01</td>
<td>1.23</td>
</tr>
<tr>
<td>Period 3</td>
<td>33.4</td>
<td>33.6</td>
<td>17.7</td>
<td>11.8</td>
<td>0.41</td>
<td>0.46</td>
<td>1.70</td>
<td>21.1</td>
<td>0.22</td>
<td>0.99</td>
<td>1.21</td>
</tr>
<tr>
<td>Period 4</td>
<td>34.5</td>
<td>33.3</td>
<td>18.9</td>
<td>9.5</td>
<td>0.51</td>
<td>0.54</td>
<td>1.96</td>
<td>22.8</td>
<td>0.20</td>
<td>1.04</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Figure 6. Phase diagram showing the change in slag composition

Figure 7. Slag phases (C) with high content of K, Si and Al were found at the surface of the pellets during the reference period, period 3 and period 4.

Figure 8. Potassium and basicity in slag
Sulphur Distribution

With the injection of BOF slag, the slag in the lower shaft becomes less basic, while the tuyere slag becomes almost neutral. That causes the sulphur released from the combustion of coke and coal to more easily be absorbed by the slag.

This trial showed that the sulphur distribution was improved when BOF slag was injected (Table VI and Figure 9). But due to a very low slag volume, the sulphur concentration increased in both the hot metal and slag. The increase was greater in the slag than the hot metal.

Raceway Conditions

During the final 8 hours of operation of one campaign in the Experimental Blast Furnace, a different injection was performed with each tuyere as follows:

- Tuyere no. 1: no injection,
- Tuyere no. 2: coal injection,
- Tuyere no. 3: coal and BOF slag injection.

The amount of coal injected was 45 kg/tHM in each of the two tuyeres with coal injection. In raceway conditions this corresponds to 135 kg/tHM for the whole furnace. The amount of BOF slag injected was 8 kg/tHM in the tuyere with slag-former injection. This corresponds to 24 kg/tHM for the whole furnace. After eight hours the furnace was stopped and quenched with nitrogen. After cooling down, the furnace/burden was excavated from the top to the tuyere level, and an examination of each raceway was done.

The difference between the raceways was significant. The raceway corresponding to “normal” conditions, i.e. coal injection, had a characteristic “bird’s nest” shape. The raceway with “all coke” and the raceway with injection of slag former together with coal powder both had a shape without any bird’s nest, which means that the end of these raceways was porous (Figure 10).

A bird’s nest is formed by the acidic slag from coal and coke which has not been drained due to poor drainage in the raceway surroundings, and the char particles that hit the wall at the end of the raceway.
DISCUSSION

The Effect of BOF-Slag Injection on the Consumption of Reducing Agents

The amount of reducing agents consumed was approximately 11 kg/tHM lower during period 4 compared to the reference period. The main reason for this is a 35 kg/tHM decrease in slag volume which corresponds to ~7 kg coke. The decreased Si content in the hot metal also corresponds to a decrease in consumption of reducing agents of approximately 10 kg/tHM [13]. However, in this test the average hot-metal temperature increased from 1416°C during the reference period to 1423°C during period 4. At the same time, the C content increased from 4.12 % to 4.24 % by weight.

The Effect of BOF-Slag Injection on Slag Formation

In Table VII estimated chemical component concentrations of the bosh slag after 100% reduction of the iron oxide for the reference period and period 4 are given. As can be seen, the basicity (B2) values are quite similar but the Bells basicity is much lower for period 4 compared to the reference period. Table VII also presents the estimated chemical composition data for the tuyere slag. The basicity of the tuyere slag significantly increased and the alumina content decreased considerably when BOF slag was injected. The melting behavior of the tuyere slag, shown in Figure 11, was estimated by calculations done using the computer program Chemsage [9]. This program uses a thermodynamic data file [10][11] for multi-component slags. The temperature for formation of the first melt is increased, and the temperature at which >80% of the slag has melted is decreased. This results in a more narrow softening and melting temperature interval for the tuyere slag, and it could be expected that the viscosity also decreases when BOF slag is injected. This might be the main reason why no birds nest is formed in the end of the raceway.

The Effect of BOF-Slag Injection on Hot metal Composition

The Si content of hot metal at a certain hot metal temperature decreases significantly when BOF slag is injected through the tuyeres. One important mechanism providing the hot metal with Si is considered to be SiO gas generation at the high temperatures in the flame zone and reduction of SiO2 in the slag by C in the coke at temperatures above 1700°C. When BOF slag is injected, the basicity of the tuyere slag increases significantly, and thereby the activity of SiO2 in the tuyere slag is decreased. The MgO content also increases and as a result the wettability of the slag decreases. These effects reduce the generation of SiO gas. If the partial pressure of SiO gas is very high at the tuyere level, decarburization of the hot metal can occur due to the reaction SiO+C→Si+CO, and can predominate over the carburization reaction [7].

The amount of Si reduced from SiO2 in the slag is also expected to be decreased by the gradually decreased slag volume. However, the results indicate that the effect of the changed conditions in the raceway is the main reason for the decreased Si content of the hot metal. According to the test results provided in Table III and Table V, the Si content of the hot metal during Period 1 is much lower than during the reference period. The slag amount is slightly lower, the carbon content and the Hot-Metal temperature slightly higher, but the Si content is considerably lower during Period 1 than the reference period. No further decrease in the Si content was found when the slag volume was lowered.

Table VII. Estimated chemical component concentrations (by weight) of the bosh and tuyere slag formed during the trial

<table>
<thead>
<tr>
<th></th>
<th>Bosh slag</th>
<th>Tuyere slag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference</td>
<td>Period 4</td>
</tr>
<tr>
<td>CaO</td>
<td>35.9%</td>
<td>33.1%</td>
</tr>
<tr>
<td>MgO</td>
<td>11.2%</td>
<td>7.2%</td>
</tr>
<tr>
<td>SiO2</td>
<td>39.9%</td>
<td>38.5%</td>
</tr>
<tr>
<td>Al2O3</td>
<td>5.5%</td>
<td>10.1%</td>
</tr>
<tr>
<td>Na2O</td>
<td>0.7%</td>
<td>1.6%</td>
</tr>
<tr>
<td>K2O</td>
<td>0.5%</td>
<td>0.6%</td>
</tr>
<tr>
<td>MnO</td>
<td>2.1%</td>
<td>1.0%</td>
</tr>
<tr>
<td>B2</td>
<td>0.90</td>
<td>0.86</td>
</tr>
<tr>
<td>Bells Ratio</td>
<td>1.64</td>
<td>1.19</td>
</tr>
</tbody>
</table>

Figure 11. Estimated melting behavior of the tuyere slag formed during the trial.
The Effect of BOF-Slag Injection on Distribution of Alkalis

The K refining did not change significantly when the slag rate was considerably decreased to only 101 kg/thm. Both K and Na are re-circulated as a result of reduction and gasification from slag droplets trickling through the dripping zone and from coke and coal burning in the combustion zone. If the basicity of the dripping slag is decreased, the activity of potassium in the slag phase will be decreased, and the re-circulation of potassium will be limited. The temperature at which K is reduced from potassium-silicates is decreased when CaO is present. The re-circulation will decrease when the addition of limestone is decreased. The ascending gaseous alkalis condensates from 1000°C and the highest concentration in the iron ore is reached just before melting. The distribution of alkali is highly dependent on the shape of the cohesive zone as well as on the raceway conditions [7][12]. If Bells basicity is considered the basicity will be significantly lower during period 4 compared to during the other test periods and the reference period. No limestone was added from the top either. This might partly explain the fact that the recovery of alkalis was also high during the last period of the test when the slag volume was 101 kg/thm.

The Effect of BOF-Slag Injection on Sulphur Distribution

From the estimations made it was found that the properties of the tuyere slag greatly changed when BOF slag was injected through the tuyeres. The increased length of the raceway and the porous end found in examining the raceway after quenching of the Experimental Blast Furnace indicates that the tuyere slag properties improved. The increased basicity is beneficial for absorption of S released when coal and coke are combusted. The decreased melting point and viscosity improve the S refining as well. This can explain the gradually improved sulphur distribution during the test periods.

SUMMARY

During a 2-week period in November 2000, co-injection of BOF slag and pulverized coal was tested in LKAB’s experimental blast furnace at MEPOS. The ferrous burden was 100 % pellets. The objective was to improve slag formation by fluxing the tuyere slag and to avoid an excessive slag basicity in the lower shaft. During the last part of the trial no additional slag-forming material was charged from the top and all fluxes, i.e. BOF slag, were injected through the tuyeres.

Excellent blast furnace performance was achieved during the trial. The operation was very smooth and stable. The slag volume was around 100 kg/thm and the reductant rate was lowered by 11 kg/thm compared to the reference period. A significant reduction in the hot metal silicon content (-0.3 %) was reached and analyses showed very small variation in the silicon content. Sulphur distribution between slag and hot metal was improved, as well as the output of K2O by the slag.

Quenching of the Blast Furnace, followed by dissection of the raceway area, showed that the formation of a bird’s nest can be avoided when the acidic slag, normally generated in the raceway, is fluxed with BOF slag. We believe that the injection of fluxes opens up new opportunities for further development of the blast-furnace operation.

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REFERENCES


