SLAG BEHAVIOUR IN LKAB PELLET AT ELEVATED TEMPERATURE

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ABSTRACT

Integrated steel plants in Europe operate with mixed burdens with sinter as major burden constituent and some plants use only pellet as burden material. It is important that pellet behaviour is well suited for different blast furnace burdens. Therefore it is necessary to understand pellet behaviour during reduction. As the raw material costs has increased rapidly during the last couple of years blast furnace burden materials is an important area for optimising the economy of the blast furnace process.

Pellet development at LKAB comprises formulation of pellet formula and testing in laboratory scale. The LKAB Experimental Blast Furnace (EBF) is an excellent tool to verify experimental pellet behaviour, here laboratory equipment and EBF-data was used to outline pellet behaviour at elevated temperature.

1. INTRODUCTION

LKAB is a mining company situated in northern Scandinavia. Manufacturing of blast furnace- and direct reduction pellets and sinter fines is made at three separate production sites. Total amount of finished products is in excess of 20 Mton/year. Development route at LKAB comprises laboratory scale testing, pilot scale testing and full scale testing, Fig. 1. The LKAB EBF is a unique test facility for blast furnace materials. It is a important tool in terms of product development and process research, in addition the risks involved in full-scale production trials can be avoided.

![Fig. 1 Development route at LKAB](image)

To examine blast furnace burden material in laboratory environment softening and melting equipment is used. Around the world numerous of different test set up exists\(^1\) with specific characteristics. At Studiengesellschaft für Eisenerzaufbereitung (SGA) in Germany a test method, the REAS test, has been developed to outline blast furnace burden material during reduction, softening and melting\(^1\). In this investigation the REAS-test equipment is used to evaluate LKAB pellets in laboratory environment. The EBF is used when a comparison is made during blast furnace operation.

2. EXPERIMENT

2.1 Laboratory equipment
The REAS-test set up has already been described in detail\(^1\) and will only be discussed briefly here. In Fig. 2 a schematic view of the REAS-test is shown.

Fig. 2 Schematic view of softening and melting unit

Burden material to be tested is mounted in between graphite layers and a thermocouple in the burden material is monitoring increase in temperature. Inlet gas is preheated and outlet gas is analysed to make reduction and reducibility calculations. When sample reaches a differential pressure of 200 mmWG gas is by-passed to let molten material drip into the crucible. Weight change of dripped out material is monitored at increasing temperature. Furnace is heated electrically up to 1550 °C and temperature- and gas flow control during this evaluation is shown in Fig. 3. Hydrogen and alkali reactions is not simulated in the REAS-test.

<table>
<thead>
<tr>
<th>Temperature control</th>
<th>Gas flow control</th>
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<tbody>
<tr>
<td>Temperature range</td>
<td>Heating rate</td>
</tr>
<tr>
<td>20-450 °C</td>
<td>5 °C/min</td>
</tr>
<tr>
<td>450-900 °C</td>
<td>10 °C/min</td>
</tr>
<tr>
<td>900 °C</td>
<td></td>
</tr>
<tr>
<td>900 °C - T(_{\text{max}})</td>
<td>5 °C/min</td>
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</tbody>
</table>

Fig. 3 Gas- and temperature control of test unit

2.2 The LKAB Experimental Blast Furnace

The LKAB Experimental Blast Furnace has been described in several publications\(^2-4\) and will be briefly outlined here. Burden material are screened at +6 mm for pellet, 6-50 mm for sinter, coke 15-30 mm and fluxes 10-20 mm. Iron ore is stored in one of four bins, coke is stored in a larger bin. A skip transport material to a receiving hopper. Either a bell or a rotary Top Charger is used to charge the burden material. While using the bell system there is a movable armour for distribution control. Pebbles heaters provides up to 1250 °C in blast temperature. The blast enter the blast furnace through one of three tuyeres. The tuyeres are separated by 120 degrees and has a diameter of 54 mm resulting in a blast velocity of 150 m/s at normal blast volume. One tap hole is used and normal tap to tap time is one hour. Top gas is transported through the uptakes and down comers to a dust catcher. Top gas is further cleaned in a venturi scrubber and a wet electrostatic precipitator. Finally the top gas is flared in a torch. During operation it is possible to collect material or gas and temperature profiles by inburden probes, Fig. 4. Horizontal probes can be positioned at five different heights and one inclined probe collect material from bosh area. A vertical temperature measurement give the temperature profile over the blast furnace height.

Fig. 4 The LKAB Experimental Blast Furnace

As to now the experience is that the EBF is a very sensitive tool for detecting differences in properties for different pellet types\(^5-6\). The response time is much shorter for the EBF compared to a commercial furnace. Evaluation of data and comparison to full-scale operation has been described\(^3\).

3. RESULTS AND DISCUSSION
Composition of blast furnace burden material that was tested in the REAS-test and in the EBF is shown in Table 1.

**Table 1** Pellet composition of pellet grades

<table>
<thead>
<tr>
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<th>Olivine</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>66.45</td>
<td>66.51</td>
</tr>
<tr>
<td>B2</td>
<td>0.24</td>
<td>0.23</td>
</tr>
<tr>
<td>MgO/SiO2</td>
<td>0.78</td>
<td>0.23</td>
</tr>
</tbody>
</table>

When temperature is increased pellet experience softening before melting and in the REAS-test softening is defined at attained pressure drop of 200 mmWG. Acid pellet show a sharp peak at lower temperature compared to olivine pellet, Fig. 5.

![Fig. 5 Softening behaviour of pellets](image)

In addition, the total amount of dripped mass is higher for the acid pellet grade. From Fig. 8 it is seen that the amount of primary slag for acid pellet is higher and attain in a more narrow temperature interval.

![Fig. 7 Melting behaviour of acid and olivine pellet](image)

![Fig. 8 Formation of primary slag of pellets](image)

The effect of pellet basicity on dripping temperature, Fig. 6, show higher dripping temperature at increased basicity B3. At lower temperature acid pellet start to drip and the amount of primary slag is higher compared to the olivine pellet, Fig. 7.

![Fig. 6 Effect of pellet basicity on dripping temperature](image)

During campaign 12 trial with acid and olivine pellets were conducted. Blast parameters, injection rate, slag volume and burden distribution was kept constant to make the evaluation easier. In this study an attempt is made to link the REAS-data with the EBF-data in terms of the high temperature region. Heat loss at tuyere is higher for acid pellet grade, Fig. 9.

![Fig. 9 Development of tuyere heat loss and hot metal temperature over time](image)
From operational data burden resistance index is calculated and within each period the permeability is decreasing for increasing heat loss at tuyere. Fig. 10.

**Fig. 10** Permeability at varying heat level

From the REAS-test it is shown that the acid pellet soften at lower temperature compared to the olivine pellet and that the olivine pellet experience better permeability at higher temperature. The fayalitic nature of the primary slag of acid pellet contribute to the formation of larger amount of primary slag at shorter temperature interval. With lower softening and melting temperature of the acid pellet it is expected that the cohesive zone would be located at a higher position in the blast furnace compared to the olivine pellet burden. Results based on excavated material (3) from the EBF confirm the higher cohesive zone position of acid pellet. For each pellet grade the burden resistance index is increasing with increasing heat loss but there is a difference in level when comparing the two pellet grades. Furthermore higher heat losses for the acid pellet indicate a higher position of the cohesive zone and larger burden resistance index for the olivine pellet indicate that the cohesive zone is thicker than in the case of acid pellet. Also, higher burden resistance index can be an effect of the surrounding temperature in the case of olivine pellet with its lower cohesive zone position.

**4. CONCLUSIONS**

The REAS softening and melting test can be used to simulate the softening and melting phenomena of blast furnace burden. An attempt is made to link burden behaviour in laboratory softening and melting test to EBF-data.

Based on laboratory tests and results from the EBF it is possible to describe softening and melting behaviour of different pellet types during blast furnace operation.

For evaluation of blast furnace burden material and blast furnace operation research LKAB has an important tool in the Experimental Blast Furnace.

REFERENCES