Correlation Between Pellet Reduction and Some Blast Furnace Operation Parameters

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INTRODUCTION

Modern blast furnace ironmaking aims at lowering consumption of reduction agents. Coke consumption is decreased while the amount of injected pulverized coal is increased. As the ore-to-coke ratio increases, so does load on the charged materials. An increased pulverized coal injection (PCI) will among other things affect the composition of the ascending reduction gases, the in-furnace temperature isotherms and possibly the position of the cohesive zone; all parameters important for the reduction of iron oxides. The loss of pellet strength depends on the reduction gas composition1.

As a result of increased PCI the Si content in molten metal tends to increase, and it is assumed that the pulverized coal type will have an influence on the Si content under high PCI operation2. In-furnace isotherms for 1000°C, determined with a feed-type vertical probe, go up in the shaft with the increase of PCI3. As a consequence, the cohesive zone will move upwards resulting in an increase in high-temperature furnace volume and a decrease in low-temperature furnace volume, and thus a possible decrease in the amount of indirect reduction of pellets. Due to the amount of volatile matters in the coal, increased PCI increases the H₂ content in the reducing gas4. H₂ is associated with higher reducing ability compared to CO. Indirect reduction of FeO by CO is exothermic, but endothermic by H₂5. Direct reduction of FeO by C to Fe is a strong endothermic reaction.

It is of interest to study the effect of high PCI on pellet reduction properties and to determine if the H₂ in the reduction gas increases the indirect reduction to compensate for the loss of low-temperature furnace volume. It is also of interest to understand if an increased amount of FeO will reach the high-temperature zone and possibly affect the hot metal Si content. According to Loo et al., low-temperature disintegration increases the longer materials are subjected to low temperatures in the range 300-600°C6. From this point of view, the low-temperature disintegration would decrease if the PCI rate were increased.
The reduction behaviour of olivine pellets and the textures formed during laboratory reduction simulating hypothetical PCI rates are investigated. Reduction degrees and pellet strength attained in the LKAB Experimental Blast Furnace (EBF) using different levels of PCI and types of coal are discussed as well as the reduction gas compositions under the different process conditions. Possible correlations between pellet reduction behaviour and Si content in hot metal are discussed.

MATERIAL

Commercial olivine pellets are used in the investigations performed. Material samplings for the laboratory investigations are carried out at the LKAB pelletizing plant in Malmberget and at the SSAB BF No. 3 pellet-charging stream. The chemical composition of the olivine pellets MPBO and KPBO produced by LKAB can be seen in Table I.

<table>
<thead>
<tr>
<th>Pellet</th>
<th>Fe</th>
<th>FeO</th>
<th>CaO</th>
<th>SiO₂</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>CaO/SiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPBO</td>
<td>66.8</td>
<td>0.5</td>
<td>0.35</td>
<td>1.7</td>
<td>1.5</td>
<td>0.32</td>
<td>0.21</td>
</tr>
<tr>
<td>KPBO</td>
<td>66.6</td>
<td>0.4</td>
<td>0.46</td>
<td>2.0</td>
<td>1.5</td>
<td>0.23</td>
<td>0.23</td>
</tr>
</tbody>
</table>

During the EBF campaign MPBO is delivered by lorry from the pelletizing plant. Two different coal types are used in the investigations, a low-volatile coal containing 19.6 percent volatile components and a high-volatile coal containing 38.0 percent volatile components.

EXPERIMENTS

The Laboratory Reduction Furnace

The experimental apparatus used for reduction tests I-XII (see Table II), is shown in Figure 1. The furnace is a vertical steel tube-type furnace with an inner diameter of about 60 mm and is heated electrically by U-shaped Super-Kanthal elements with a constant temperature zone of about 80 mm in height. Digital Multi-Bus Flow-Bus regulators control the gas flows of H₂, CO, CO₂ and N₂. The gas is introduced in the bottom of the tube and heated in a bed of crushed ceramics. A thermocouple for temperature measurement and control is introduced from the bottom of the tube and situated approximately 20 mm below the sample, which is suspended in the balance with metal wires. The sample material is placed in a basket with three different levels. A water-cooled top for cooling of the sample after test completion is situated on top of the steel tube. A propane off-gas burner is placed on top of the furnace. Input gas composition and temperature are controlled and measured by a computer storing data with a frequency chosen for each parameter.

The furnace is heated to the start temperature of the test without any input gas. At the test start temperature a nitrogen flow at 12 l/min is introduced. The temperature and gas flow are held at constant values for a few minutes before the sample is introduced into the furnace. Sample start weight is between 70 and 85 grams of pellets and drying of the pellets is carried out outside the furnace prior to reduction. As soon as the sample has been introduced into the constant temperature zone, the test is started and the temperature program starts at the same time as the gas composition is changed into a reducing atmosphere. After the test, which can be interrupted at any point, the gas is changed into pure N₂ and the sample is put into the cooling top. Total gas flow is maintained at 12 l/min during the entire test.

In one laboratory test program the temperature and gas profiles are based on a normal test procedure at LKAB. Two temperature profiles are used in the study. The slow heating rate is based on a normal test procedure at LKAB and the fast heating rate is based on a vertical temperature measurement made in the EBF during a PCI rate of approximately 130 kg/tHM. The gas compositions used for the different hypothetical process conditions with all-coke operation and hypothetical PCI rates are calculated using mass and heat balances for estimation of the gas composition at various levels in the blast furnace. Changing the hypothetical PCI rate mainly...
influences the H₂ content in the gas. Test conditions are shown in Figure 2. Nitrogen is filled up to maintain the total gas flow at 12 l/min during the tests. Table II gives an overview of the experiments performed.

![Image of temperature profiles](image_url)

Figure 2 Reduction profiles for calculated hypothetical all-coke, a PCI rate at 200 kg/tHM and a normal LKAB test. Slow temperature profile (left), and fast temperature profile based on a vertical temperature measurement in the EBF (right).

Table II Schematic overview of blast furnace simulating reduction experiments performed.

<table>
<thead>
<tr>
<th>Test</th>
<th>Material</th>
<th>Temperature Profile</th>
<th>Gas Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>MPBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>KPRO</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>I</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>II</td>
<td>X</td>
<td>X</td>
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</tr>
<tr>
<td>III</td>
<td>X</td>
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<td>IV</td>
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<td>V</td>
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<tr>
<td>VI</td>
<td>X</td>
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<tr>
<td>VII</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>IX</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>XI</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>XII</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*Sampled at the pelletizing plant at Malmberget. *2 Sampled at SSAB Tunnplåt at Luleå.

EBF

The EBF has a working volume of 8.2 m³ and a diameter at tuyere level of 1.2 m. The height from tuyere level to stock line is 6 m and there are three tuyeres separated by 120°. After a campaign, the furnace can be quenched. The process is interrupted, nitrogen throughput from the top is started, followed by a decreased and finally stopped blast. Dissection of the EBF can start after at least ten days of cooling and is carried out like an archaeological excavation. Basket samples introduced in the final hours of operation are recovered.

During operation, in-burden probes are used for sampling of the burden and for the measurement of the horizontal temperature- and gas profiles. The shaft probe material is divided in sub-samples. A packed probe will during ideal conditions generate 5 sub-samples for the higher probe and 6 for the lower. It is common that only 3-4 sub-samples are generated for each probe. A schematic drawing of the EBF can be seen in Figure 3.

![Schematic drawing of the EBF](image_url)

Figure 3 Schematic drawing of the EBF. Positions of probes and basket samples recovered at excavation indicated.
In the EBF the pellet properties attained at the probe positions are investigated during operation with different PCI rates and injection of the high and the low-volatile coal. Using the low-volatile coal the average PCI rates are 152 and 79 kg/tHM, respectively and for the high-volatile coal 152 and 94 kg/tHM. The material sampled from the shaft probes is sieved and the pellet fraction >6.3 mm recovered. The strength of pellets taken out with the upper shaft probe are tested in an I-trommel with a diameter of 130 mm and a length of 700 mm. 300 grams of pellets in the size range 10-12.5 mm are rotated 600 times at a revolution of 20 rpm. Flue dust and sludge are sampled every fourth hour during the test periods with different process conditions.

**SSAB Blast Furnace No. 3**

At SSAB Tunnplåt, BF No. 3 produces about 2.2-2.3 M tonnes of hot metal every year. The ferrous burden consists entirely of olivine pellets. Two thirds of the average burden is MPBO and one third KPBO. The chemical composition can be seen in Table I. The low gangue content and good metallurgical properties of the olivine pellets together with the relatively low ash content of coke at SSAB are the main attributes for the high productivity and low slag volumes. Design data of BF No. 3 are presented in Table III.

<table>
<thead>
<tr>
<th>BF No. 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of erection</td>
<td>2000</td>
</tr>
<tr>
<td>Design</td>
<td>SSAB/Kvaerner</td>
</tr>
<tr>
<td>Start of campaign</td>
<td>Aug. 2000</td>
</tr>
<tr>
<td>Hearth diameter, m</td>
<td>11.4</td>
</tr>
<tr>
<td>Working volume, m³</td>
<td>2540</td>
</tr>
<tr>
<td>Total volume, m³</td>
<td>2850</td>
</tr>
<tr>
<td>No of tuyeres</td>
<td>32</td>
</tr>
<tr>
<td>No of tap holes</td>
<td>2</td>
</tr>
<tr>
<td>Runners</td>
<td>Replaceable troughs</td>
</tr>
<tr>
<td>Top pressure, kPa</td>
<td>150</td>
</tr>
<tr>
<td>Charging equipment</td>
<td>BLT central feed</td>
</tr>
<tr>
<td>Daily output, tonnes</td>
<td>6700</td>
</tr>
</tbody>
</table>

Raw material samplings are carried out over a period of a few days at the pellet feeders close to the blast furnace. Process data, including the hot metal Si content, are stored at the same time. Low-temperature reduction disintegration tests are performed according to ISO13930, except for the pellet size fraction where pellets from the total samples are used instead of the 10-12.5 mm fraction. The reduction strength, ITH, is determined according to the description of Hooey et al. but pellets from the total samples are also used in this case.

**RESULTS**

**Laboratory Reduction for All-Coke and Hypothetical PCI Rates**

Increasing the hypothetical PCI rate increases the degree of reduction at any temperature once the reduction degree has reached about 10 percent; a pattern that is independent of temperature profile, see Figure 4. The most apparent difference in reduction behaviour is observed between a hypothetical all-coke case, tests I and IV, and a hypothetical PCI at 146 kg/tHM or 200 kg/tHM, tests II or III and V or VI. A clear difference between the hypothetical PCI rates of 146 and 200 kg/tHM, tests II and III is observed for the slow temperature profile at temperatures above 750°C.

![Figure 4](image)

Figure 4 Temperature- and reduction profiles for laboratory reduction tests simulating hypothetical all-coke and different PCI.

Significant differences in the iron oxide and Fe$_{met}$ textures after reduction are not observed when pellets from tests II and III are compared. Wustite is dominating in the pellet cores with a small number of Fe$_{met}$ areas. The size and number of the Fe$_{met}$ areas increase in the reaction fronts. After test III, Fe$_{met}$ dominates the pellet peripheries and after test II, Fe$_{met}$ surrounded by wustite.
dominates. Some areas of magnetite, surrounded by wustite, are found in the pellet cores and reaction fronts. In pellets from test I magnetite dominates the pellet core and wustite and Fe\textsubscript{net} the periphery. The area between the core and the periphery is made up of wustite. A few Fe\textsubscript{net} areas are observed inside the pellet periphery and in the pellet cores. Typical textures from test I and III are presented in Figure 5.

In pellets from reduction tests IV-VI, areas of Fe\textsubscript{net} are observed in the entire pellet cross section after tests V and VI. In pellets from test IV, Fe\textsubscript{net} is observed together with wustite and some magnetite in the pellet periphery. Magnetite dominates in the core and wustite in the area between the core and the periphery. In the pellet cores after test V and VI, wustite dominates, which is also the case in the area between the core and the pellet periphery. Magnetite is observed through the entire cross section of the pellets. Fe\textsubscript{net} and wustite dominate the pellet periphery. Typical textures from test IV and VI are presented in Figure 6.

**EBF Operation using Different PCI Rates and Injection Coal Types**

Figure 7 shows the horizontal profile of the reduction gas composition as percentages H\textsubscript{2} and \(\eta\textsubscript{CO}\).

\[
\%\eta\textsubscript{CO} = 100\%\text{CO}_2/(\%\text{CO} + \%\text{CO}_2),
\]

at the position of the upper shaft probe during the four test periods. An increase in the H\textsubscript{2} content is observed when the PCI rate is increased and is most distinct when the high-volatile coal is injected. As can be seen from the H\textsubscript{2} and \(\eta\textsubscript{CO}\) profiles, during the tests, the reduction potential of the reducing gas is higher in the centre of the furnace, position 0, and decreases towards the periphery. The high PCI rate generates the highest \text{CO} content. The H\textsubscript{2} content during the EBF tests is in general at a higher level at the lower shaft probe due to the difference in temperature at the position of the shaft probes.
Figure 7 \( \text{H}_2 \) and \( \eta_{\text{CO}} \) profiles at the position of the upper shaft probe in the EBF during tests with different PCI rates and a low and a high-volatile injection coal type. Position 0 indicates the centre of the EBF and the positive and negative extremes the periphery.

The particle size distribution of material taken out with the upper shaft probe and the content of Fe and C in the <0.5 mm fraction can be seen in Figure 8. The fine fractions, 0-0.5 mm, 0.5-3.3 mm and 3.3-6.3 mm, constitute a larger part of the material using the high-volatile injection coal compared to operation using the low-volatile coal. The Fe content in the <0.5 mm fraction increases at the same time as the C content decreases when the high-volatile coal is injected at the high PCI rates.

Figure 8 Particle size distribution in the total material samples taken out with the upper shaft probe (left) in the EBF for different process conditions. Fe and C content in the <0.5 mm fraction for corresponding samples (right).

Injection of the high-volatile coal results in the highest reduction degree of pellets taken out with the upper shaft probe. Correlations between operation parameters and the pellet reduction degree are not observed at the level of the lower shaft probe. The pellet reduction degrees reached in sub-samples 1-3 during the test periods are presented in Figure 9. The results from the I-trommel tests are presented in Figure 10. The highest amount of the fraction >6.3 mm is found during injection of the high-volatile coal type, indicating low disintegration, but it also shows the highest amount of abrasion in the <0.5 mm fraction. As can be seen in Figure 11, a linear relation is obtained between the pellet reduction degrees and the disintegration. The highest pellet strength and the highest reduction degree are measured in samples taken during injection of the high-volatile coal.
Figure 9 Pellet reduction degrees in sub-samples from samples taken out with the upper (left) and the lower (right) shaft probe in the EBF.

Figure 10 Pellet strength after I-trommel test of sub-samples taken out with the upper shaft probe.

Figure 11 Relation between pellet reduction degree and pellet disintegration in probe samples taken out with the upper shaft probe in the EBF.

The amount of flue dust and sludge generated per tonne of hot metal is shown in Figure 12. The total amount of fines leaving the furnace with the top gas reaches the highest level injecting the high-volatile coal. Figure 13 shows the amount of Fe and C in flue dust and sludge at different process conditions. Injection of the high-volatile coal increases the Fe content in the flue dust at the same time as the amount of C decreases.
Figure 12 Amount of flue dust and sludge generated per tonne of hot metal under different process conditions.

Figure 13 Weight percent of Fe and C in flue dust (left) and sludge (right) at different process conditions in the EBF.

Evaluation of Process Data and Pellet Samples from SSAB Blast Furnace No. 3

During the material sampling period, the Si content in the hot metal reaches between 0.15 and 0.54 percent and decreases are observed between observation 19 to 28 and 38 to 49, see Figure 14. The 74 Si observations correspond to measurements during 48 hours. Samples of MPBO and KPBO for further testing are chosen during a period of increase and decrease in the Si content in hot metal. Sampling occasions A-H and the relation to the hot metal Si content are marked in Figure 14, which also shows the PCI rate during the period in question. The particle size distributions are shown in Figure 15. Low-temperature reduction disintegration and the reduction strength for the investigated samples are shown in Figure 16.

Figure 14 Si content in hot metal during the raw material sampling period and A-H samples used for metallurgical testing (left). PCI rate and the relation to hot metal Si content during the same period of time (right).
Considering the >6.3 mm fraction, the lowest, highest, and a median value correspond for the low-temperature reduction disintegration of MPBO to samples B, G and E, respectively, and for KPBO to samples B, F and G, respectively. The reduction strength in the >6.3 mm fraction reaches the lowest, highest and a median value for MPBO in samples B, E and G, respectively, and for KPBO in samples B, G and F. Reduction profiles of the MPBO samples B, E and G (tests VII-IX, see Table II) and KPBO samples B, F and G (tests X-XII, see Table II) indicate almost the same reduction behaviour, see Figure 17.

After reduction, Fe\textsubscript{met} is dominating in the pellet peripheries and a few small areas are found in the pellet core. Wustite dominates the cores and some magnetite is observed. The areas of Fe\textsubscript{met} grow at the reaction front and the pore sizes are larger compared to the appearance in the cores. Differences in Fe\textsubscript{met} texture are observed between the pellet types. The MPBO samples show larger areas of coherent Fe\textsubscript{met} in the pellet peripheries compared to the KPBO samples. Figure 18 shows typical textures of the MPBO and KPBO pellets.
At the EBF excavation after campaign No. 12, basket samples containing material from the same samples as tests VII-XII are recovered below the position of the upper and lower shaft probes, see Figure 3. The reduction degrees, calculated with respect to the weight loss, are about 30 percent for the upper samples and between 38 and 52 percent for the lower samples. Magnetite and wustite dominate the pellet textures at a reduction degree of 30 percent, although small areas of Fe_{met} can be found. The size and number of Fe_{met} areas increase with increasing reduction degree. All of the basket samples containing the same material as in tests VII-XII show for the same pellet type similar iron oxide and Fe_{met} textures after reduction in the EBF.

**DISCUSSION**

**Effects of PCI Rate and Coal Type**

In the EBF, pellets in samples taken out with the upper shaft probe have during injection of the high-volatile coal reached a higher level of reduction degree compared to pellets in samples taken during injection of the low-volatile coal. The H_{2} content at the level of the upper shaft probe is higher during high PCI rate of the high-volatile coal compared to during injection of the low-volatile coal. Increasing the PCI rate increases the H_{2} content of the gas independent of the coal type. The differences in \( \eta_{CO} \) are quite small and consequently, the changes in reduction potential under different process conditions seem to be more or less dependent on the H_{2} content. Because of central coke charging, the reduction potential of the gas is higher in the centre. Although there are differences in gas composition, no significant differences in reduction degrees can be correlated to the PCI rates at the position of the upper shaft probe. Temperature measurements indicate that temperature isotherms in the reserve zone move upward in the shaft when the PCI rate is increased. In pellets taken out with the lower shaft probe, significant differences in average reduction degree are not found. The results indicate that the test conditions, in terms of the reduction potential of the gas, temperature profile and time for all cases, result in an extension of the thermal reserve zone that is sufficient for reduction of pellets under all the investigated process conditions.

Since no significant differences in average reduction degrees in pellets taken out with the lower shaft probe are observed, any differences in FeO content influencing the hot metal Si content are not expected in the EBF tests. The trend of the hot metal is decreasing Si content during the EBF test, mainly dependent on increased CaO/SiO_{2} of the slag.

During hypothetical reduction of iron oxides, a reduction degree of 13 percent corresponds to complete reduction from hematite to magnetite. Complete reduction to wustite corresponds to a reduction degree of 33 percent. The average reduction degrees attained in pellets taken out with the upper shaft probe when low-volatile coal is injected are 17 and 25 percent. The average reduction steps, from magnetite to wustite, are endothermic at indirect reduction by CO as well as H_{2}. When injecting the high-volatile coal the average reduction degrees attained in pellets taken out with the upper shaft probe are 37 and 42 percent. The average indirect reduction steps are from wustite to Fe_{met} endothermic by H_{2} and exothermic by CO.

Since the indirect reduction of wustite by H_{2} is endothermic, but less endothermic at increased temperatures, it is assumed to take place in the lower part of the shaft. A high H_{2} content in the reduction gases, as attained at high PCI rate, results in an increased average indirect reduction by H_{2} in the lower part of the shaft. Investigations of the pellets taken out with the lower shaft probe do not show whether the indirect reduction at this position is predominantly by CO or H_{2}.
Injection of the high-volatile coal generates the highest amount of fine material in the fractions 0-6.3 mm taken out with the upper shaft probe. When the share of the 0-0.5 mm fraction increases in the total material samples, the analysis of corresponding samples shows an increased amount of Fe at the same time as the C content decreases. Injection of the high-volatile coal at the high PCI rate increases the Fe content in the fines in the material taken out with the upper shaft probe. The generation of and Fe content in flue dust increase when injecting the high-volatile coal. The highest pellet strength is observed at the highest reduction degrees attained when high-volatile coal is injected; however, an increased abrasion in the 0-0.5 mm fraction is also evident, resulting in higher Fe losses through the top gas. Comparing temperature profiles in the upper part of the shaft based on vertical temperature measurements, the production rate and rate of descent, it is probable that the dwell time in the upper part of the EBF is approximately the same at different PCI rates, and correlations between the PCI rates and low-temperature disintegration are not found in the tests performed.

Changing the PCI rate affects the temperature and gas profiles in the blast furnace. Adjusting the laboratory conditions to different PCI operations, an increased heating rate is assumed to correspond to an increase in PCI rate. Considering laboratory tests I-VI, an increased hypothetical PCI rate increases the reduction degree attained. At equal hypothetical PCI rate the highest reduction degree is reached for the slow temperature profile. Approximately equal reduction degrees are attained for tests I, slow temperature profile and hypothetical all-coke, and VI, fast temperature profile and a hypothetical PCI rate of 200 kg/tHM. In this case an increase in hypothetical PCI rate is necessary to compensate for the decrease in reduction time between the slow and fast temperature profiles. When the PCI rate in the blast furnace is increased the laboratory investigations indicate that an increased H2 content in the reduction gas can compensate for the possible loss of low-temperature volume, which is confirmed by the EBF test.

The amount of Fe formed in the pellet periphery increases when increasing the hypothetical PCI rate in samples I-VI. The slow heating rate and consequently an increased test time result in peripheries containing a higher amount of Fe compared to pellet peripheries from fast heating rate tests. At a hypothetical PCI rate of 200 kg/tHM the areas of Fe met in the pellet periphery become denser when increasing the reduction time.

**Process Observations and Pellet Properties at SSAB**

Although differences in low-temperature disintegration and reduction strength are observed in pellet samples taken out at SSAB in connection to increases and decreases in the hot metal Si content, no major differences in reduction behaviour and pellet textures after reduction are observed. The differences in hot metal Si are assumed to be a consequence of different PCI rates used to obtain the best possible process conditions. In the SSAB BF No. 3 the pellets are exposed to different conditions as a result of the process control. Possible differences in the pellet reduction behaviour in the upper part of the shaft are assumed to recede in the shaft and not affect the hot metal Si content. During the pellet-sampling period the high-volatile coal is injected in the SSAB BF No. 3, which verifies the assumption of equal pellet reduction attained in the lower shaft. In the laboratory tests the conditions are equal for tests VII-XII and, consequently, the absences of differences in pellet reduction behaviour are not surprising.

**CONCLUSIONS**

The reduction properties of MPBO are well suited for stable blast furnace operation under different PCI rates. Injection of the high-volatile coal results in a higher reduction degree of pellets in the upper shaft. The differences in reduction degree recede through the shaft. The pellet strength, measured by I-trommel test on pellets in sub-samples taken out with the upper shaft probe in the EBF, increases when injecting the high-volatile coal. At the same time, the pellet abrasion, considering Fe met in flue dust and the <0,5 mm fraction after I-trommel test, increases.

At a high laboratory hypothetical PCI rate the Fe met texture in the pellet periphery becomes more compact with increasing reduction time.

Differences in hot metal Si content in a production blast furnace are difficult to correlate to raw material properties, since the process conditions are constantly changed in order to control the heat level of the blast furnace.

**ACKNOWLEDGEMENTS**

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