THE INFLUENCE OF SLIME ON THE EFFECTIVENESS OF THE SINTERING PROCESS

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Abstract

Dusts and slimes from the production of iron and steel are a very valuable raw material owing to their high contents of iron and MgO. High contents of harmful compounds, including those of zinc, lead and chlorine, causes some limitations in their reusing in the sintering process. Investigations carried out were aimed at the determination of the effect of slime addition to ore mix on process efficiency and the mechanical properties of the sinter. The microscopic examination of the sinter was performed in order to detect differences in the structure, which might indicate the causes of the sinter strength change that occurs in the case of sinters made from mixes with a slime addition.

1. INTRODUCTION

As a result of dust removal in the technological processes of iron and steel manufacture, dusts and slimes are produced. These differ substantially, in terms of both chemical composition and graining. In domestic conditions, due to the recycling of dusts and slimes to the sintering process, so called averaged slime forms. Partially dewatered and mixed with dusts, it has a pasty consistency, which makes it necessary to comminute it prior to adding to the ore mix. This slime is characterized by high contents of iron and harmful compounds, such as those of zinc, lead and chlorine, of which it is the main source in the sintering process (Table 1) [1,2].

Table 1. Chemical composition of slime used for tests.

<table>
<thead>
<tr>
<th>Material</th>
<th>Share, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H\textsubscript{2}O</td>
</tr>
<tr>
<td>Slime</td>
<td>18,93</td>
</tr>
<tr>
<td>Share, %</td>
<td>Na\textsubscript{2}O</td>
</tr>
<tr>
<td>Slime</td>
<td>0,230</td>
</tr>
</tbody>
</table>

The aim of tests carried out was to determine the effect of the slime addition in the ore mix on the achievable efficiency of the sintering process and the mechanical properties of sinter. The process efficiency was calculated based on the amount of sinter of a grain-size above 6 mm, obtained from the drop test (1):
The drop test is one of the methods allowing the determination of the mechanical properties of sinter, namely its strength (2) and crumbling toughness (3). It involves dropping the sinter three times from a height of 2 metres to an inelastic ground.

Sinter strength:

\[ W = \frac{M_2}{M - M_1} \times 100\% \]  

(2)

- \( W \) – sinter strength,
- \( M_2 \) – mass of the sinter of a grain-size above 6 mm after three drops,
- \( M \) – overall sinter mass (used for the drop test),
- \( M_1 \) – mass of the sinter of a grain-size below 6 mm after one drop.

Sinter crumbling toughness:

\[ R = \frac{M_1}{M} \times 100\% \]  

(3)

- \( R \) – sinter crumbling toughness,
- \( M \) – overall sinter mass (used for the drop test),
- \( M_1 \) – mass of the sinter of a grain-size below 6 mm after one drop.

2. SINTERING OF MIXES WITH SLIME ADDED

The sintering of mixes was done on a sintering pane of a diameter of 100 mm and a layer height of 300 mm. In order to verify the accuracy of obtained results, two sintering operations were performed assuming that obtained respective results might not differ from each other. Prior to sintering, the mix was pelletized in a plate mixer for a duration of 1.5 minutes with an addition of water. The addition of water was dependent on mix humidity and was balanced up to 8%. The testing mix was chosen based on previously performed experiments aimed at achieving the highest possible efficiency of the iron ore sintering process. To the ore mix (40% of hematite ores and 60% of magnetite concentrates) 2% of burnt lime and 5% of quick coke were added. The amount of return sinter was balanced up to 30%. In the case of mixes without the return sinter, the share of quick coke was increased to 7% due to a higher process demand for heat and a much longer sintering time. The amount of slime was either 0; 3; or 9%, depending on the mix. The composition of mixes is given in Table 2.

On the first stage, the sintering of mixes without a return sinter addition was done. In connection with the planned analysis of sinter structure, the aim of the first stage was to produce returns for the purposes of subsequent tests. During sintering the mix without slime, the process progressed for a characteristically long time, typical of mixes without return sinter. In the case of mixes with slime added, a very interesting observation was made. As little as 3% of slime share leveled out the difference during the time of the sintering process. This resulted in a considerable increase in process efficiency, which was close to the one obtained when sintering mixes with return sinter (Figure 1).
Table 2. Composition of mixtures used for tests – the materials are given in a natural state.

<table>
<thead>
<tr>
<th>Material</th>
<th>Determination of mixtures and share of materials in mixtures, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M1A</td>
</tr>
<tr>
<td>iron ore - m1</td>
<td>0,696</td>
</tr>
<tr>
<td>iron ore - m2</td>
<td>0,695</td>
</tr>
<tr>
<td>iron ore - m3</td>
<td>0,694</td>
</tr>
<tr>
<td>iron ore - m4</td>
<td>0,687</td>
</tr>
<tr>
<td>iron ore - h3</td>
<td>1,814</td>
</tr>
<tr>
<td>slime</td>
<td>?</td>
</tr>
<tr>
<td>lime</td>
<td>0,088</td>
</tr>
<tr>
<td>dolomite</td>
<td>0,068</td>
</tr>
<tr>
<td>limestone</td>
<td>0,410</td>
</tr>
<tr>
<td>quick coke</td>
<td>0,359</td>
</tr>
<tr>
<td>return sinter</td>
<td>?</td>
</tr>
</tbody>
</table>

Figure 1. Sintering process efficiency reached for mixtures with a slime share of 0, 3, 6, 9%, respectively, with and without return sinter – average values.

1 – \( r = 0,7485, p = 0,2515; y = 1776,1408 + 59,8212x \),
2 – \( r = 0,9181, p = 0,0082; y = 1200,6612 +133,6244x \),
3 – \( r = 0,4357, p = 0,5643; y = 1380,5312 + 14,5772x \).
Despite increasing the share of quick coke in the mix without return sinter, the strength of produced sinter was higher by only approx. 2%. At the same time, a decrease in the grain-size fraction above 10 mm (by over 6%) was observed. The obtained sinter exhibited high porosity – excessively large voids formed as a result of the evaporation of water concentrated in the slime. As a consequence of a low permeability of the mix free from return sinter, a situation appeared, where the slime water, by changing its state of aggregation, formed a gas bubble within the mix. This, in turn, as a result of growing pressure, led to a disruption of the sinter before the end of its final crystallization. For this reason, the sinter was obtained in the form of numerous lumps of a size of 20–50 mm, instead of a solid “cylinder”.

In the case of mixes with return sinter, an increase in process efficiency was noted for mixes with a slime share above 5% (Figure 2). At the same time, the strength and share of skip sinter fraction above 10 mm was reduced. Converting the efficiency for the sinter with a grain size above 10 mm, the increase in efficiency is negligible.

Figure 2. Efficiency, sintering time, share of skip sinter fraction above 10 mm and strength of sinter for mixtures with a slime share of 0, 3, 6, 9%, respectively – average values.

1 – \( r = 0.7485, p = 0.2515; y = 1776.1408 + 59.8212x \),
2 – \( r = -0.8374, p = 0.1626; y = 89.5292 - 0.1171x \),
3 – \( r = -0.7997, p = 0.2003; y = 0.2030 - 0.0055x \),
4 – \( r = -0.8204, p = 0.1796; y = 79.3696 - 0.7958x \).

The strength properties of sinter were in this case little lower than after the sintering of the mix without return sinter and with a quick coke share of 7%. The share of the fraction below 10 mm in the skip sinter was, on the other hand, lower. This indicates a better utilization of heat derived from the quick coke. It happens so owing to a 30% share of return sinter introduced to the mix. This is associated with the number of water supplied to the pelletizing process. In the case of so large share of slime in the mix, the water goes to the mix to a considerable extent with the slime. The very fine graining of the slime prevents water...
from escaping to the surface of the pellets. Thus, it does not come to its concentration in the lower part of the mix layer. The confirmation of this analysis is a very porous and reductive sinter forming in the lower part of the sintering pane. In the case, where mix layer becomes too wet, an excessive partial melting of the material occurs, which decreases both the sinter parameters and the sintering process parameters.

In the tests carried out, no significant differences in charge permeability were noted. This fact should be explained by the possibility of sucking so called “wild” air through the leaks in the sintering pane system. Also the temperature of combustion gas did not change significantly.

MICROSCOPIC ANALYSIS OF SINTER

The obtained iron ore sinters showed similar strength parameters and chemical composition. Depending of the slime share in the mix, the produced contained 60?61% Fe, and its (CaO/SiO$_2$) basicity was approx. 1.40.

The microscopic observation at a magnification of 1000 times revealed a significant difference in the structure of the sinters analyzed. Figures 3a and 3b show the structure of the sinter obtained from mixes, respectively, without slime and with a 9% share of slime. The sinters obtained as a result of the sintering of the mix without slime feature a homogeneous structure. In the case of sinters obtained from the mixtures with slime added, an eutectic structure is visible, which increases the brittleness of the sinter and its susceptibility to mechanical damage.

In the photographs, a (white) silicate phase surrounding the (white) magnetite can be seen. In the case of self-fluxing sinters with a basicity of approx. 1.40, the silicate phase is made up chiefly of calcium olivines and dicalcium silicates. At the same time, the share of calcium ferrites in the sinter is sufficiently high (the prevalence of calcium ferrites over calcium olivines in amount). This has a favourable effect on the strength properties of the sinter, while retaining its good reduction properties [3].

Figure 3. Sinter structure after the sintering of the mix: a – without slime, b – with a 9% share of slime. Magnification 1000x. Non-etched specimens.

SUMMARY

The use of slime in the iron ore sintering process in the conditions of the Polish metallurgical industry is at present necessitated by the lack of possibilities of slime storage. Despite the observed increase in efficiency in the case of sintering mixes with a slime addition of over
using slime in its present form is not advantageous either from the technological or economic points of view. The first main problem occurring in industrial conditions is the lack of possibility of uniformly distributing the slime in the mix. In such a case – this is particularly true for a high layer of sintered mix characterized by low permeability – there will be a tendency to the concentration, in some places, an excess of moisture which, by changing its state to a gaseous one under high temperature, will impart a damaging effect on the sinter, causing its comminution. Moreover, slime causes the brittleness of sinter. As a consequence, a very large amount of the fraction of a grain size below 10 mm will form. By converting the efficiency for a grain size above 10 mm it can be seen that there is almost no increase in efficiency.

In summary, it should be stated that:

?? for the mix type tested, the addition of slime to the ore mix in the amount of above 5% intensifies the sintering process, thereby causing the process efficiency to grow, on the assumption that the sinter of a grain size above 6 mm is classified as skip sinter;

?? the decrease in sinter strength does not negatively affect the achievable efficiency, as this is more than offset by the increased intensity of the sintering process with the addition of slime; and

?? increasing sinter brittleness associated with slime added does not lead to an excessive comminution of the sinter.

BIBLIOGRAPHY