NEGATIVE ELEMENTS IN BLAST FURNACE PROCESS

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Abstract

The global economic crisis has significantly affected the production of iron and steel. The dramatic increase in prices of all input resources has meant a substantial interference with the cost parts of the production processes. Blast furnace process is one of the most demanding production processes. It poses great demands both on input raw materials, regulation on the process flow, but also on the amount of used human capacity to ensure an efficient workflow. The continuous increase in prices of raw materials forces the metallurgical companies to increase the efficiency of the process. Disrupting the blast furnace process may bring not only technological problems, but, secondarily, also substantial increase in production costs. The input raw materials for iron production can often contain a number of negative elements. These elements in the form of compounds can later disrupt the entire process of production of pig iron. Harmfulness of the individual elements must also be considered in terms of their effects in other steel production operations. Many elements do not have negative effects throughout the entire blast furnace process, but have negative impact later, during steel production. Other substances may have negative impact not only on the primary or secondary metallurgy, but they can have crucial effect on the environment. In general, we can say that the disruption of blast furnace process brought by negative elements is determined by a number of significant causes. These causes later most often lead to abrupt changes in gas-flow speed or to a disproportional decrease of the charge. They can also cause change of viscosity or excessive heating of the blast furnace hearth. The article analyzes the amount and impact of negative elements in the blast furnace process.

Keywords: costs, blast furnace process, sulphides, continuous

1. INTRODUCTION

The main requirements on the production of iron are continuous flow of the entire process and maximum production of metal with appropriate chemical composition [1]. Another important aspect is to execute the production process at a competitive level of costs. All these parameters can be guaranteed only with quality raw material base and smooth operation of the blast furnace. The amount and the impact of harmful elements in the blast furnace process represent a key point here. The classification of harmful elements is made more difficult due to their different impact on various stages of the technological process. The negative elements contained in blast furnace raw materials cause many problems affecting the properties of coke and the sintering process, as well as the production iron itself. They are mainly heavy metals and alkaline carbonates. In case of alkaline carbonates, there are many negative impacts on various stages of the blast furnace process, but, at the same time, these compounds also support some effects, such as the reduction of slag viscosity.

Disruption of blast-furnace process is raised by a number of typical causes which most often lead to sudden changes in gas flow speed or decreased charge, and cooling or excessive heating of the furnace heart. The outcomes can be changes in slag or pig iron viscosity and problems connected with their discharge from blast-furnace [2].

The major harmful elements include especially zinc, lead, phosphorus, arsenic, but also the already mentioned compounds based on alkaline carbonates. These harmful elements and their compounds can significantly influence the course of the blast furnace process and they can also increase the production
costs [3]. As a result of that, it is necessary to pay special attention to the contents of these elements and to prevent the technological problems [4]. The objective of this article is to outline a balance of the content of K$_2$O in the input and output raw materials. The measured values were obtained within the frame of the research conducted in the monitored metallurgical company. The compiled material balance of harmful elements can contribute to more effective reduction of their content in the blast furnace process.

2. PROBLEM FORMULATION

Alkaline carbonates can significantly interfere with the course of the blast furnace process. They enter the furnaces in practically all components of blast furnace charge, mainly in ore, fuel and metallurgical wastes. With regard to the coking process, we can generally state that the amount of alkaline carbonates remains virtually unchanged throughout this process. Most of the alkaline carbonates remain allocated in coke and they are passed into the blast furnace process. As far as the maximum content of alkaline carbonates is concerned, it depends on a number of technological aspects. Generally, we can say that the upper limit of alkaline carbonate content is 7.5 kg / t [5] of pig iron. In this case, we are talking about the total quantity of all compounds based on alkaline carbonates. It can be assumed that a significant share of alkaline carbonates enters the blast furnace process as part of sinter, but also as part of lump ore. Potassium carbonates melt at the temperature range of 840 °C - 900 °C [5], however they are not reduced or decomposed. Alkaline carbonates on the basis of potassium are reduced at temperatures exceeding 1180 °C. The reduction proceeds according to the following reaction [2]:

$$K_2CO_3 + CO \rightarrow 2K(g) + 2CO(g) \quad (1)$$

Gaseous potassium is one of the products of the reduction reactions. This product is then carried away by the gases flowing towards the upper parts of the blast furnace. Gaseous potassium deposits on pieces of charge in the higher parts of the blast furnace with a lower temperature, which subsequently go down the stack, as a result of continuous flow of the blast furnace process. At temperature of 900 °C, potassium along with carbon dioxide can again create carbonates [2]:

$$2K + 2CO_2 \rightarrow K_2CO_3 + CO \quad (2)$$

These newly formed alkaline carbonates, together with another batch, fall one more time into the area of higher temperatures, where the reduction process takes place again.

Alkaline carbonates have negative effect on the sintering process, quality of blast-furnace coke, quality of slag, and the lifetime of the lining. The penetration of alkaline carbonates into the lining significantly reduces the strength of refractory materials and thus the overall lifetime. That is why it is absolutely necessary to monitor the balance of harmful elements in the input raw materials and output products of the blast-furnace.

3. EXPERIMENTAL WORK

A research has been conducted in a selected metallurgical plant in the Czech Republic. The research was focused on the content of alkaline carbonates, especially K$_2$O in the input raw materials and output products of the blast furnace process. The measurement results of the research carried out last year were used to create the material balance. Table 1 shows the measured quantity of K$_2$O in all relevant input raw materials. Table 1 also shows the required amount of input raw materials per one kilogram of pig iron produced. In case of the monitored K$_2$O content, the relative content in the individual compounds, the amount of K$_2$O per kilogram of pig iron produced and the percentage content in the individual raw materials based on the total amount of K$_2$O entering the blast furnace process were determined.

**Tab. 1** K$_2$O content in the individual input raw materials
Figure 1 shows the evaluation of the overall weight shares in the individual input raw materials. Coke and coal admixture were the largest sources of K₂O in the input raw materials which accounted for 32.6% of the total content. Other important sources include Granules (21%), Sinter – A112 (19%), Sinter – A111 (18.2%). These four most important sources of K₂O account for 90.8% of the total input quantity of this pollutant into the blast furnace process. The share of the other components can be considered negligible, given this value.

![Figure 1](image.png)

**Fig. 1** Distribution of the total amount of K₂O in input raw materials

The contents of K₂O in the output products of the blast furnace process were also monitored within the frame of the conducted research project. 1 147 467 tons of iron were produced in the monitored blast furnace during the research period of time. Table 2 shows the measured contents of K₂O in the individual output products. The percentage contents of pollutants were again determined per kilogram of pig iron produced.
On the output side of the blast furnace process, the highest content of K$_2$O is, as expected, in slag (96.1 %), and the distribution of the contents of harmful elements in the individual output products is shown graphically in Figure 2. Alkali content in other products can once more be considered as negligible. The individual products contained the following percentage shares: Discharge (2.4 %), BF sludge rough (0.8 %), BF fine sludge (0.7 %).

### Table 2 K$_2$O content in the individual output raw materials

<table>
<thead>
<tr>
<th>Weight</th>
<th>Quantity</th>
<th>K$_2$O</th>
<th>% (share of the total amount)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig iron</td>
<td>1 147 467</td>
<td>1 000</td>
<td>0.00 0.00 0.00 0.00</td>
</tr>
<tr>
<td>Slag</td>
<td>444 259</td>
<td>0.387</td>
<td>0.53 2.05·10^{-3} 96.1</td>
</tr>
<tr>
<td>BF sludge fine</td>
<td>7 656</td>
<td>0.006 0.23 1.53·10^{-5} 0.7</td>
<td></td>
</tr>
<tr>
<td>BF sludge rough</td>
<td>10 542</td>
<td>0.009 0.19 1.74·10^{-5} 0.8</td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>25 265</td>
<td>0.021 0.22 4.84·10^{-5} 2.4</td>
<td></td>
</tr>
</tbody>
</table>

Alkaline carbonates have a vital impact on the viscosity of slag. As the research has proved, the largest amount of alkaline carbonates is removed especially by slag. For effective removal of these pollutants from the blast furnace process, it is important that they are concentrated just in this form, as far as the input raw materials are concerned. The problem of alkaline carbonates in production is then complicated due to the circulation of these pollutants in the blast furnace process, although carbonates of alkaline metals created immediately from the gas phase, are usually of microscopic dimensions and large part of them goes out together with the blast furnace gas.

![Fig. 2 Distribution of the total amount of K$_2$O in output raw materials](image)

Removal of pollutants in the blast furnace process is essentially possible to realize by minimizing the entry of the harmful substances into the process, or by technological interventions. The eventual reduction by means of technological interventions can be understood as the removal of alkaline metals particularly through slag. This option may be technically and economically more demanding and it is also related to the amount and alkalinity of slag.

### 4. CONCLUSIONS

The conducted research has shown that the main sources of K$_2$O in the input raw materials are especially Coke and coal admixture, Granules, Sinter - A112, Sinter - A111. Alkaline carbonates contained in the sinter
mixture can make a natural part of this raw material. In case of lump ore, they can build up on the individual parts during the continuous cycle in the blast furnace. Higher amount of alkaline carbonates in the sinter mixture has negative impact not only on the flow of the blast furnace process, but also on the sintering process itself. It has been verified that an excess amount of alkaline metals slows down the sintering process. Alkaline metals also significantly reduce especially the mechanical properties of coke, which affects its consumption. This is caused by increased degradation of coke, but also by higher consumption necessary to reduce the alkaline carbonates. Negative impact on the blast furnace lining represents another dominating consequence of the presence of alkali. The increased number of surface defects of the lining and its microstructure is directly proportional to the amount of penetrated alkaline carbonates. These harmful elements cause the destruction of both carbon and graphite lining and they create a network of cracks of different sizes.

By influencing the composition and properties of slag, we can to some extent control the removal of alkali from the blast furnace. The amount of removed alkali is directly proportional to the alkalinity and the amount of slag. The largest measured contents of K₂O in the output raw materials were monitored in slag, as expected. The content of these compounds within the frame of all the monitored output products is absolutely dominant. The minimization of their content in the input raw materials appears to be the easiest method used to reduce of the impact of alkaline carbonates in the blast furnace process. This is, however, also influenced by the economic conditions. In recent years, there has been a significant increase in the prices of all fuels and ore raw materials. Ore, but also blast furnace coke, are becoming increasingly expensive input raw materials. The competitive pressure forces metallurgical companies to buy raw materials with worse properties, which also contain significantly higher levels of negative elements. These facts naturally indicate higher volume of pollutants entering the blast furnace process and, at the same time, they increase the demands on technological production management. Monitoring the contents of harmful elements of all input sources and optimizing the composition of the charge so as not to exceed certain limit values defined on the basis of long-term operating experience remain the key recommendations for metallurgical plants in the area of the negative effects of harmful substances.

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REFERENCES


