THE IMPACT OF ZINC COMPOUNDS ON BLAST FURNACE LINING LIFE

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Abstract

The key elements affecting the technology of pig iron production include zinc and all its compounds. Zinc generally belongs to heavy metals. It has very negative impact during the production of iron, as well as on the quality of the produced metal itself. With regards to the physical and chemical properties of these metals, there is a cycle between the lower parts of blast furnace with high temperatures, which lead to reduction and vaporization, and upper parts of the furnace shaft with low temperatures, where the vapour condenses. Zinc affects especially the quality and life of blast furnace lining within the blast furnace process. Zinc gradually builds up and causes continuous degradation of blast furnace lining. The amount of zinc in blast furnace lining is different in its individual parts. This is given by the blast furnace process sequence, especially the amount of zinc entering the process in the form of the input raw materials. The research has experimentally determined the amount of zinc in the input and output raw materials and the quantities allocated in the selected parts of blast furnace lining. The objective of this article is to analyze the main sources of zinc entering the blast furnace process and to identify its effect on the life and quality of blast furnace lining.

Keywords: Iron, steel, costs, zinc

1. INTRODUCTION

Industrial production of iron from natural raw materials is currently performed using three most important technologies: production of pig iron in blast furnace, production of pig iron by means of smelting reduction, and direct production of pig iron from iron ore [1]. It must, however, be noted that approximately 98 % of produced pig iron comes from blast furnaces. Blast furnace production of iron can be classified into two basic processes. The first one is associated with the preparation of the blast furnace charge and the other one is the blast furnace operation itself [2, 3].

The input raw materials into the blast furnace process can be divided according to a number of aspects. The blast furnace charge itself consists of fuel, iron ore raw materials and fluxes [4]. All input raw materials must be supplied in such a ratio that ensures the production of certain amount of pig iron in the given quality. The function of fuel in the blast furnace is to supply sufficient amount of heat and reducing agent, to carburize iron until it is saturated and to create a solid frame, especially in the lower part of the furnace, which facilitates the flow of gases through charge at temperatures at which the ore materials soften and melt [5, 6]. The function ensuring the passage of gases from the lower parts of the blast furnace to higher ones significantly affects the entire blast furnace process. That is why coke can be pinpointed as the elementary fuel in the production of iron. Other forms of heat and reducing substances can be fed into the blast furnace process in the form of natural gas, oil or powder fuels [7].

The amount and the effect of negative elements represent an important aspect of the production of iron. The basic harmful elements in the blast furnace process include, in particular: S, P, Cd, Zn, Pb, As, Na_2O, K_2O [8]. The key elements having negative impact on the course of the blast furnace process include zinc and its compounds [9]. Zinc, as well as lead, belongs to heavy metals. These elements enter the blast furnace along with the blast furnace charge in the form of oxides and sulphides. With regards to the physical and chemical properties of these metals, the blast furnace creates a cycle between the lower parts with high temperatures, which leads to reduction and vaporization, and the upper parts of the furnace shaft with low temperatures, where the vapours condense. Zinc enters the blast furnace mainly as part of ore, but also through coke [10, 11]. Generally, it can be stated that the zinc content in sinter and pellets is higher than in natural ores. This is mainly caused by the processing of waste, such as sludge, which often contains high amounts of this element [17, 18, 19]. However, an effective utilization of all input raw materials then naturally affects the cost aspects of metallurgical production. It will always be necessary to take into account both the metallurgical factors, and the aspects affecting the overall production cost [20, 21, 22]. The objective of this article is to analyze the main sources of zinc entering the blast furnace process and to identify its impact on the quality and life of blast furnace lining. Shorter life of blast furnace lining can therefore significantly affect the costs of production of iron.

2. PROBLEM FORMULATION

Iron ores contain zinc in the form of compounds, such as: ZnS, ZnO, $ZnCO_3$, Zn_2SiO_4 and others. Zinc gets into the blast furnace from ore, but also as part of coke [12]. The zinc content in sinter and pellets is higher than in natural ores. This is the result of frequent processing of blast furnace waste materials. The amount of zinc in the blast furnace charge is crucial, especially due to its repetitive entry into the process [13, 25, 26]. Blast furnace charge moving down during the process is gradually heated up, which leads to the reduction of zinc compounds. The melting of zinc occurs at a temperature of 440°C - 930°C. In case of the presence of CaO, zinc may react according to the following reaction formula:

$$ZnS + CaO + C \rightarrow Zn + CaS + CO \quad (1)$$

The reaction of zinc directly with carbon can be generally regarded as more frequent. This is due to the fact that the contact of ZnS with iron is closer than with solid CaO. At the same time, zinc is reduced by means of CO and H_2. The fundamental problem in assessing the impact of zinc is its cycle within the blast furnace process. Reduced zinc immediately evaporates and returns with gas to the upper parts of the furnace, where the temperature is lower [14, 23]. Zinc is oxidized by means of carbon dioxide and condenses on the surfaces of larger pieces of charge. These pieces of charge gradually fall down into the lower parts of the blast furnace [15]. Here, the conditions of high temperatures logically cause vaporization. The entire process of the cycle of this element is thus continuously repeated [16, 24]. A smaller part of zinc leaves the blast furnace process as part of the output products of the process. At the same time, zinc and its compounds are further added in the input raw materials. The zinc content is therefore a key parameter that needs to be constantly monitored. The conducted research has experimentally determined the amount of zinc in the main input blast furnace raw materials. The values are shown in **Fig. 1**.

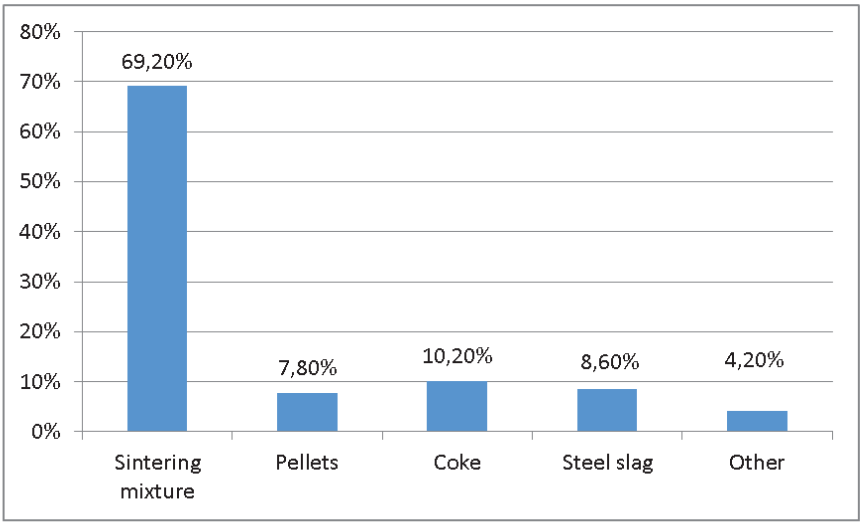

Fig. 1 Share of zinc in the basic blast furnace input raw materials

The largest share of zinc enters the blast furnace in the form of sintering mixture (69.20 %). All other input raw materials bring significantly lower shares into the blast furnace process. The highest share of zinc from other input raw materials can be found in coke (10.20 %). The amount of zinc contained in the sintering mixture can then be reduced by selecting suitable and high quality ore, but also by the composition of the sintering mixture. At the same time, its content can be reduced through suitable conditions during the mixture sintering. It can be generally stated that the amount of zinc entering the blast furnace process significantly affects its following cycle in the process and its ratio in the output raw materials.

3. EXPERIMENTAL WORK

The conducted research was focused not only on the amount of zinc in the input raw materials, but also on its content in the output products and in the individual parts of the lining. Nearly half of all zinc leaving the blast furnace process is allocated in the form of pig iron (45.60 %), as shown in **Fig. 2**. Blast furnace sludge contained an average of 31.80 % of this metal out of the total volume of the output raw materials. The throat dust and blast furnace slag are relatively insignificant in terms of the zinc content (10.20 % and 10.40 %). The majority of zinc therefore passes directly into the produced metal. That is why it is very difficult to remove zinc from the process in the form of slag, such as, for example, in case of sulphur or other negative elements.

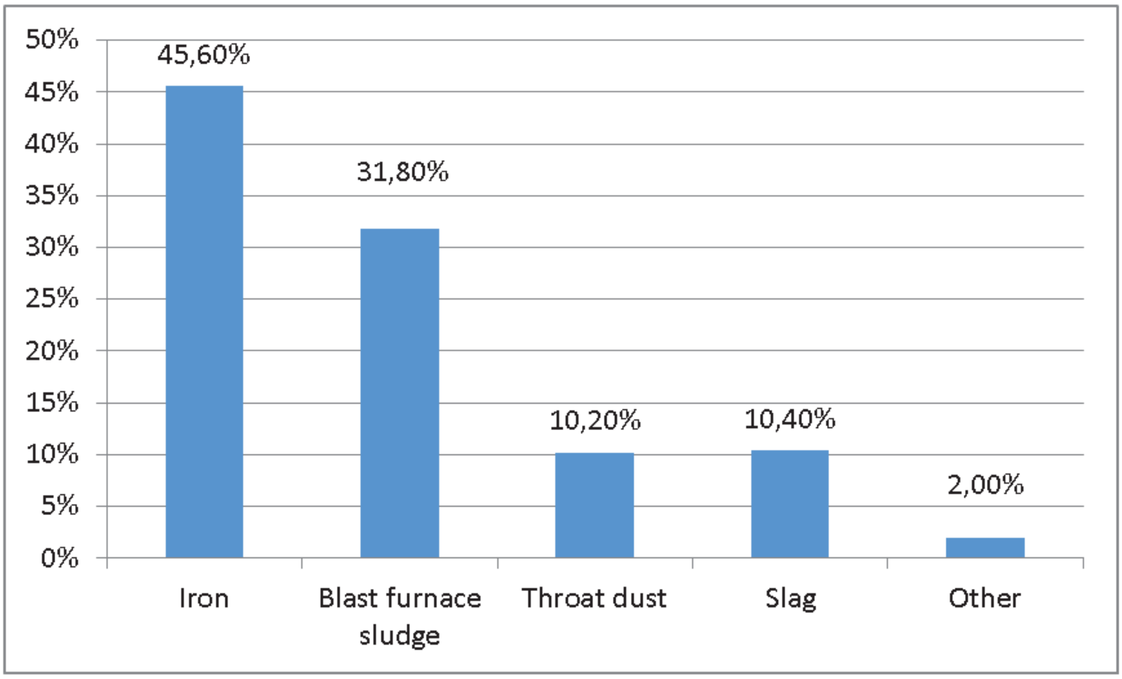

Fig. 2 Share of zinc in the basic blast furnace output raw products

The research conducted in this case also simultaneously analyzed samples of blast furnace lining which had been taken during the repair and reconstruction of the blast furnace. The analyses have shown two areas where the largest concentration of zinc had penetrated into the lining. These were areas in the upper part of the furnace (6-13 m) and in the lower part as well (18-25 m). The content of zinc and its compounds in these parts was almost twice as high as in the other parts. At the same time, the most frequent and the largest damage of the lining has also been found in these parts. This may be caused by the change in volume that occurs during the transition of zinc from gaseous to solid state. Exact data on the individual shares of zinc in the specific parts of the blast furnace are shown in **Fig. 3**.

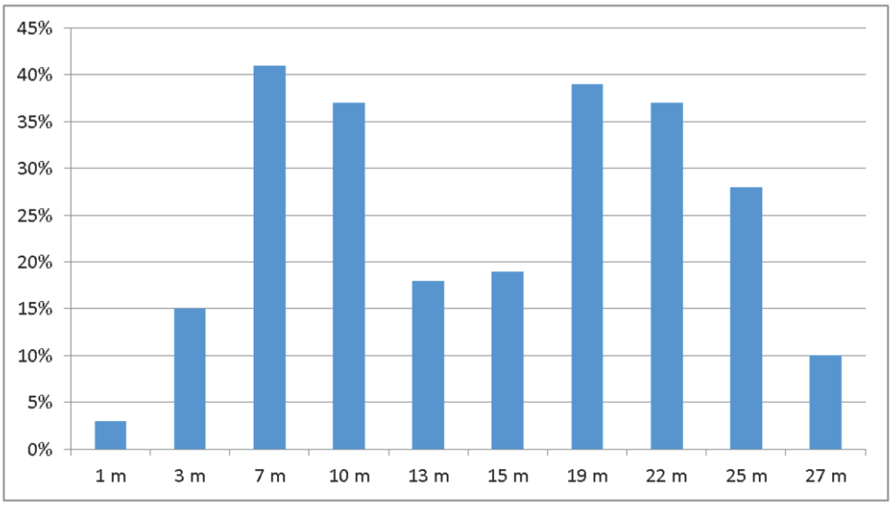

Fig. 3 Zinc content in blast furnace lining

4. CONCLUSIONS

Zinc and its compounds have a number of negative properties which manifest themselves both within the scope of the actual blast furnace process and within the scope of sintering, as well as in secondary metallurgy processes. The most important negative effects within the blast furnace process itself include mainly the consequences of the effects of zinc and its compounds on the blast furnace lining. The main causes of blast furnace lining damage include, in particular: thermal stress, mechanical stress, oxidation and reaction with alkali. In real practice, we do not see the action of one key cause, but a synergy of all these aspects, which ultimately affect the degradation of the blast furnace linings. The deposition of zinc in the blast furnace lining significantly affects its life. This is primarily due to the catalytic effect of zinc oxide. Another key factor is the formation of low-melting eutectics, or the evaporation of some of the lining components. An analysis of selected samples of lining has simultaneously identified carbon deposits around zinc silicates, which have also been frequently found in areas of significant damage to the lining surface. Crucial problems are also caused by metallic zinc vapours. They penetrate into the blast furnace lining, where they are oxidized. This is accompanied by the volume increase of metal, which ultimately causes damage to the blast furnace lining. The thermal expansion of zinc is much higher than in case of the lining itself. The amount of zinc allocated in the blast furnace lining was directly proportional to its damage and its surface defects.

The research has demonstrated that part of the oxidized zinc vapours condense on the walls in the upper sections of blast furnace. These deposits can affect the gas-dynamic conditions and disrupt the effective course of this technological process. Releasing these parts can bring potential cooling of the blast furnace hearth.

The re-entry of zinc into the blast furnace process and its negative effect on the blast furnace lining increase the requirements to reduce its content in the input blast furnace raw materials. One of the options how to reduce the content of zinc is its removal within the scope of the sintering process. It is possible to remove zinc from charge by supplying sufficient amount of fuel within the frame of the sintering process. A significant reduction of zinc can be observed with 25 % fuel content in charge. This reduction is very significant with 30% of fuel share. Higher fuel content is primarily associated with higher temperature of the sintering process. This has crucial affect on the volatility of zinc. The presence of zinc in the hot gas leaving the process can be within the interval ranging from 30 to 160 mg of zinc / m^{-3}.

Generally, it can be stated that increasing the fuel content in the sintering mixture creates favourable reducing conditions for the removal of zinc in the sintered mixture. However, these reduction conditions are very unfavourable from the viewpoint of the removal of sulphur from the sintering mixture. One of the ways of removing zinc from the sintering process is also the addition of $CaCl_2$. This compound significantly contributes to the evaporation of zinc during sintering. The amount of zinc, which is transferred in the form of sintering mixture into the blast furnace, is primarily determined by its amount in the input sintering raw materials.

Zinc in the blast furnace process affects not only the quality of the produced metal, the lining life, but it can also affect the working environment. Zinc allocated in charge is exposed to direct reduction in the hearth and tuyeres section, and it is transferred into pig iron. The hot issue here is the fact that it oxidises during tapping. White gas, which predominantly contains ZnO and PbO, is formed during the oxidation. This gas can have adverse affect on the working environment and the health of employees. Determining the maximum limit of zinc in the blast furnace is always very individual. It is always necessary to consider a number of factors, such as the construction of the blast furnace, the wall thickness, the type and intensity of cooling, and the useful volume of the blast furnace.

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