INFLUENCE OF SELECTED BATCH PROPERTIES ON THE OPERATION OF IMPERIAL SMELTING FURNACE

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Abstract

One of the currently used industrial methods of zinc and lead production is Imperial Smelting Process, based on the use of a shaft furnace. It was created for the processing of traditional minerals of both metals that form compounds with sulfur. Their processing involves the necessity of removing sulfur from the materials before applying them to the furnace. This task is carried out by a specially constructed sinter plant, which also prepares the furnace charge for physical and chemical properties. In recent years, the necessity has become the processing of increasingly-occurring post-production waste containing Zn and Pb on the market, in which the carriers of these metals are ZnO and PbO. These wastes are characterized by very diverse physical properties that negatively affect the sintering process and, as a consequence, the use of such wastes for sinter plant operation, and especially of the shaft furnace. The influence of these properties of materials on the agglomeration process and consequently the production effects of zinc and lead were analyzed. An industrial test was carried out to explain the influence of metal-bearing material size distribution on production effects such as fuel consumption, production, etc.

Keywords: Batch permeability, sinter grain size, zinc and lead production, Imperial Smelting Furnace

1. INTRODUCTION

Blast furnaces for the production of zinc and lead have been constructed to recover these metals from the minerals found in the earth's crust. The basic fossil minerals Zn and Pb are sulphides, carbonates and, more rarely, silicates and oxides. In the case of the ISP process, the first group of minerals is the most important. Both the furnace construction itself and the accompanying installations were designed for the processing of sulphide batch. In particular, this applies to the sinter plant preparing the charge for the needs of the shaft furnace, the structure of which is adapted to capture the sulfur that separates in the process of agglomeration, directing it in the form of gas to the sulfuric acid plant where it is managed.

In recent years, significant amounts of waste products from other processes, containing zinc and lead, appear on the market. Both metals in these materials are in the form of oxides. The increased price of traditional zinc and lead ores has also been observed for some time. The necessity of using oxide waste materials forced the producers to adapt technologies to their processing due to maintaining production continuity, but also to improve economic results [2]. It was considered that a better solution would be to separate both types of feed. This led to dividing the furnace working time into an oxide and sulphide campaign. They are implemented alternately and a single campaign lasts about a month. The introduction of oxide charge for production carries a number of complications. They mainly concern the units preparing the sinter mix and the sintering process of the materials themselves, but also in some elements of the actual zinc and lead production process in the shaft furnace.

The article presents influence of ISF batch characteristics on its industrial operation at zinc smelter HCM in Miasteczko Śląskie (Poland).

2. CHARACTERISTICS OF SINTER PLANT OPERATION

The charge for the oxide campaign is collected during the period of the previous processing of sulphide materials. An example of a set of materials collected for the needs of the oxide campaign with shares of selected components is presented in **Table 1**.

Table 1 Set of waste materials used in oxide campaign of ISF [HCM data]

Internal name of waste material	Component (wt.%)							
	H_2O	Zn	Pb	Fe	SiO_2	CaO	MgO	Al_2O_3
Ash Germany	0.78	69.16	0.81	1.50	1.94	0.71	0.14	9.00
Ash Zn	0.48	44.70	1.41	5.40	4.47	0.31	0.12	23.67
Concentrate PbZn	9.70	22.08	37.58	0.75	4.36	2.89	2.12	0.94
Granular oxide	10.57	47.58	13.43	2.20	1.10	3.69	0.47	0.36
Hydroxide	27.75	41.27	3.12	10.35	4.75	5.14	4.09	0.96
Oxide 1	0.40	58.36	2.17	1.03	5.27	1.56	0.30	2.19
Oxide 2	0.50	55.48	0.16	13.22	0.10	0.07	0.03	12.75
Oxide 3	3.30	62.49	1.02	9.87	1.36	0.53	0.11	4.53
Oxide 4	5.56	54.8	2.69	1.75	4.95	0.89	0.23	1.38
Oxide Romania	0.28	50.73	21.56	1.69	1.05	0.71	0.07	0.47
Oxide Turkey	2.00	64.14	6.24	1.67	0.32	3.61	0.23	0.10
Oxide England	23.24	51.72	4.38	1.94	1.72	2.96	0.97	2.64
Oxide with Ag	27.79	35.12	7.49	7.29	7.11	4.94	5.37	0.82
Waelz oxide	22.56	66.12	4.87	1.87	0.78	2.90	0.31	0.26

As can be seen, the shares of key components in particular materials undergo large fluctuations. This applies mainly to lead and, to a lesser degree, zinc. However, the proportion of water in a significant amount of materials for the production of sinter mix is particularly striking. An important component is also iron, whose reduction with the creation of a separate liquid phase in the shaft furnace is unacceptable from the point of view of durability of the furnace [3]. Another disadvantage is the physical properties of oxide materials that complicate the production of the sinter mix. Most of them are in the form of dust and even sludge. The creation of a sinter mix exclusively from such materials precludes the possibility of sintering due to the insufficient air permeability. Hence it is need to use a sintered powder as the main component of the mixture. Such technology drastically affects the efficiency of the sinter plant. It can be assumed that the normal applied in practice addition of sintered powder to the mixture is from 70 % to 80 % of its total mass.

Laboratory tests of sludge mixture permeability, using real batch materials, with variable addition of sintered sinter were carried out. A specialized device was used for the tests, and the air permeability index was adopted for R. Voice [4] as in equation (1):

$$P = \frac{V}{A}\frac{S^{0.6}}{h^{m}} \tag{1}$$

where:

- P - R. Voice permeability index ($m^3/m^3 \cdot h$)
- V - volume of blown air (m^3/h)
- A - crossed area of mix layer (m^2)
- h - height of mix layer (m)
- S - pressure of blown air (mm H_2O)
- m - coefficient of moisture absorption, for ores 0.4 (-)

Figure 1 shows dependence of permeability index on share of return sinter in the mix, height of mix layer and pressure of blown air.

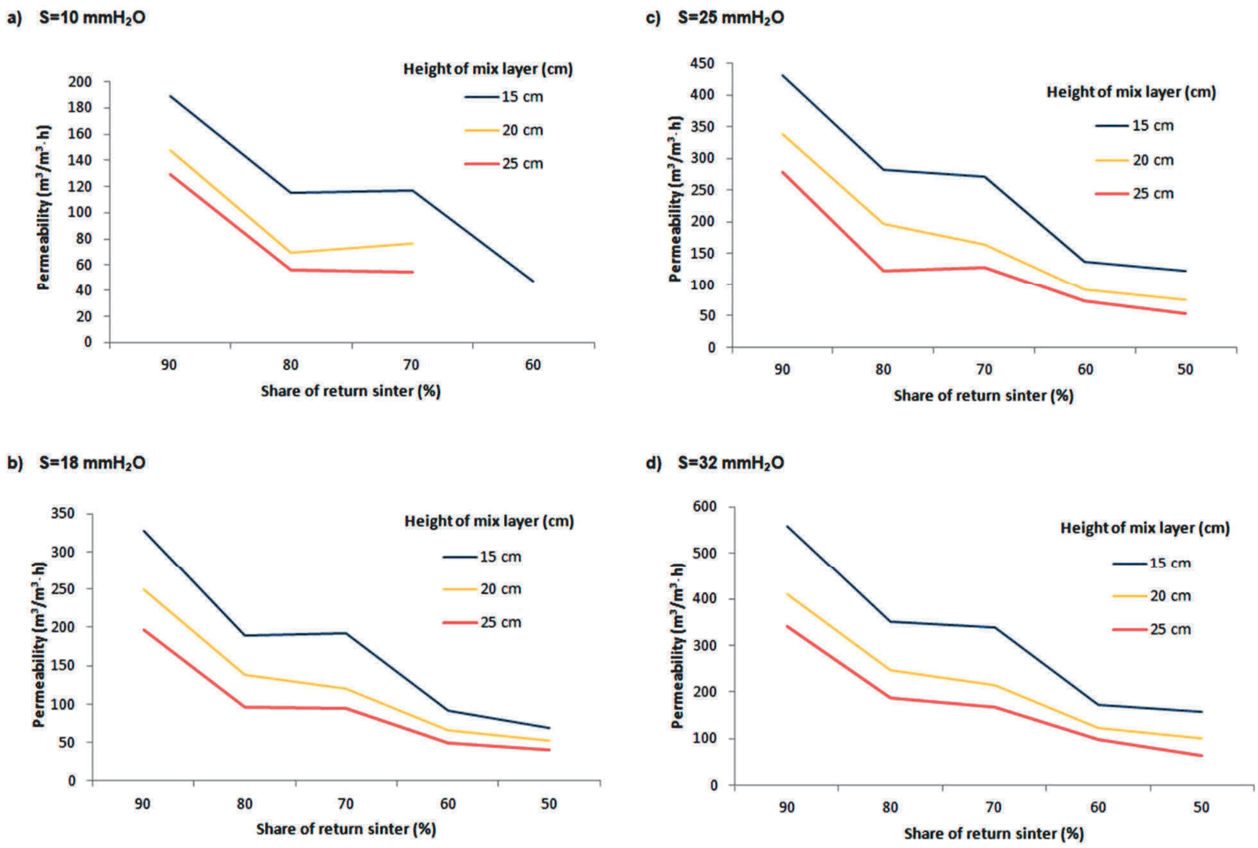

Figure 1 Dependence of permeability index on share of return sinter, height of mix layer and pressure of blown air

The obtained results indicate that the addition of return sinter in amount of about 70 % is the lowest to ensure the sintering process. It should be noted, that only 30 % of the sintered product will be delivered as a furnace charge. On the one hand, the efficiency of sinter production is difficult to accept, but on the other hand, such technology results in very high stabilization of the sinter's chemical properties, constituting about 97 % of batch for the blast furnace.

Another complication of the technology used is the recycling of sinters in the production process, a material with finer grains. Due to the scale of the grinding turns, the material with the optimum grain size for the oven also goes. On the other hand, the material with the largest grain goes as an input to the shaft furnace.

3. INFLUENCE OF INCREASED SINTER GRAIN SIZE ON THE ISF OPERATION

Generally, in a shaft furnace, the sinter is evaluated in terms of strength and reducibility. Strength is influenced by the chemical composition of the material and the manner in which the agglomeration process is carried out. Reducibility is a more complex indicator. It depends on the chemical composition, the type of compounds that make up the metals, but also on other factors, the most important of which is the graininess of material charged to the furnace. It follows that the total value of this indicator can be influenced by the selection of the reacting phases surface. If the contact surface is more extensive, the reduction process will intensify, including indirect reduction. In the case of the furnace for the production of zinc and lead, the system of temperature zones is selected so as to counteract reoxidation carried with zinc gases. For this reason, the temperature of the flue gas should exceed 900 °C. Thus, almost the entire column of materials in the reactor working space is in the Boudouard reaction zone. It is therefore possible to assume a large advantage of endothermic direct reduction over indirect reduction. Zinc almost entirely will give oxygen with the participation of Boudouard reaction. In the case of lead, which is reduced at lower temperatures, a certain share of indirect reduction is possible. The larger the share, the better the utilization of the gas reduction potential and the lower fuel consumption in the furnace. Intensification of indirect lead reduction, with a stable chemical composition of the sinter is possible by selecting the optimum granularity of the batch. This feature of the charge, apart from the impact on the intensity of reduction processes, including indirect ones, also affects other elements of the shaft furnace operation. In the case of too small granules of batch, one can expect an excessive increase in resistance to gases flowing to the top of furnace, with constant values of pressure loss, a decrease in production resulting from the counter-current nature of the process. In the opposite situation, the charge of excessive chunkiness, the negative effect is the descent of unreacted feed material into the lower regions of the furnace.

As part of the project supporting the presented work, at the blast furnace in HCM Miasteczko Śląskie was carried out an industrial test to investigate the impact of sinter size on the reducing ability of the gas phase and fuel consumption. Changes in the sinter grain size were made by the gap size adjusting of the crushing unit, located between the sinter plant and the blast furnace. The normally used gap size is 140 mm. This resulted in the following sinter grain distribution (**Table 2**).

Table 2 Sinter grain size distribution and ISF operation data in dependence of crusher gap size during industrial test

Crusher gap size (mm)	**Share of sinter grain size** (wt.%)				**Top gas** (vol.%)		**Coke consumption** (kg/tonne Zn)
	0-20 (mm)	**20-100** (mm)	**100-150** (mm)	**>150** (mm)	**CO**	**CO_2**	
140 (referenced)	1.64	28.39	33.76	36.21	31.80	6.62	1060
130	3.99	33.23	31.86	30.91	29.03	7.47	1047
110	6.25	38.14	29.41	26.34	28.40	7.17	970

The next step was to reduce the gap size of the crusher to 95 mm, but the attempt was not continued. As the crusher gap decreased and sintering grain size changes changed, the demand for sinter as a batch grew, and reached a critical state at the 110 mm gap of the crushing device. Concerns arose that during the continuation of the test, a batch deficit would occur which would necessitate the braking of the furnace. As the large (>150 mm) and medium (100-150 mm) sinter grain was reduced, the furnace working space was improved, which resulted in an increased demand for the batch. In the case of 70-80% addition of sinters to the sinter mix, this deficit could not be eliminated and the test had to be stopped.

From **Table 2** can be seen that with decrease of sinter big grains the coke consumption significantly dropped. It may be explained as following. Decrease of sinter granularity has intensified the process of lead reduction in the upper layers of the shaft. This was accomplished by improving the contact of the gas and solid phase, consisting in the expansion of the reaction surface intensifying the reduction process [5]. At the same time, the endothermic direct reduction process was deteriorated, which resulted in a dropping of fuel consumption and probably an increase in production.

4. CONCLUSION

A (Zn-Pb) batch for the Imperial Smelting Furnace working in zinc smelter HCM in Miasteczko Śląskie, consists of about 97 % sinter produced in its own sinter plant. In the case of an oxide campaign, the sinter mix is made from a significant number of components constituting post-production waste. They are diversified in terms of their chemical composition and, above all, their physical properties make it impossible to carry out the sintering process as it takes place in iron ore sintering process. Hence, forced return sinter additions of a selected granularity to the sintering mixture are used and thus giving it sufficient breathability. These additives reach in practice up to 80% of sinter production. In addition, as the furnace charge the largest pieces are placed and create an unfavorable grain system. The permeability test of the sinter mix showed, that the optimal addition of the return sinter is about 70 wt%.

However, industrial grain size test of sinter used as batch in ISF showed a favorable direction in changing the flue gas composition (CO, CO_2) and reducing the consumption of coke.

Therefore, improving the ISF operation should be associated with the optimization of the grain size of loaded sinter and also decreasing of the return sinter share in the sintering mix. It is possible to consider, if necessary, methods of pre-treatment of materials for the sintering process, such as, for example, granulation, which may reduce the amount of recycled sinter and allow the furnace to work freely with a feed of smaller average grain.

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