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APPLICATION OF ANTHRACITE DUST IN THE PROCESSING OF STEEL DUSTS

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Scrap processed in the electric arc furnace (EAF) process in the form of car bodies or housings of household appliances generates dust containing a large amount of zinc. Coke or anthracite is currently used as a reducer in pyrometallurgical technologies used for the processing of waste zinc-bearing materials. The article presents the results of research on a large-laboratory scale, in which anthracite dust was used as a waste reducer. The presented research confirmed the high efficiency of the reducer used. The degree of zinc removal in the process of steel dust processing in the kiln was at the level of 80 %. Such values indicate that waste anthracite dust can be an alternative carbon-bearing material in the process of steel dust processing.

Keywords: anthracite dust, steel dust, rotary kiln, zinc, laboratory research

INTRODUCTION

The feedstock used in the electric steelmaking process in the form of post-amortisation scrap – mainly from car bodies and housings of household appliances – results in a relatively high zinc content in the Electric Arc Furnace Dust (EAFD) produced in the process, significantly exceeding its content in the ore. Currently, several technologies, mainly pyrometallurgical, are used on an industrial scale for the recovery of zinc and accompanying metals. These technologies are based, among other, on reduction processes in which coke or anthracite are the most frequently used reducers [1-3].

Recent years characterised by a significant increase in their use have brought a clear increase in their prices. This has become an incentive to search for less expensive alternative fuels. The quality requirements for such raw materials, set by end users, make it necessary to have comprehensive information to what extent they may turn out to be useful in a given technological process. Waste carbon-bearing materials and biomass are used as alternative fuels and reducers for applications in the pyrometallurgical processes of processing primary and secondary raw materials.

The article presents the results of research on the use of waste anthracite dust in the process of steel dust processing in a rotary kiln.

ROLE OF CARBON IN THE ROTARY PROCESS

In each of the methods of processing zinc-bearing dust in rotary kilns, the same chemical reactions between the feedstock components and coal take place, leading to the elimination of zinc into gas phase [4].

$$C + 0{,}5O_2 \Rightarrow CO_2 \quad (1)$$

$$C + CO_2 \Rightarrow 2CO \quad (2)$$

$$Fe_2O_3 + CO \Rightarrow FeO + CO_2 \quad (3)$$

$$FeO + CO \Rightarrow Fe + CO_2 \quad (4)$$

$$ZnO + CO \Rightarrow Zn_{(g)} + CO_2 \quad (5)$$

The course of these reactions shows that it acts as a component of the feedstock; as a result of its combustion, carbon monoxide is obtained, which is the basic reducing agent for zinc oxide and iron oxides contained in the feedstock. Also during the process, zinc vapours oxidise and other feedstock ingredients react with one another. The latter relates to the formation of $nCaO \cdot mFeO \cdot pFe_2O_3$ ferrites.

MATERIALS FOR TESTING

The study used steel waste dust, the chemical composition of which is presented in Table 1. Anthracite dust was used as a reducer. Technological additives included hydrated lime and silica. The characteristics of the anthracite dust are presented in Table 2 [5-10].

Table 1 **Chemical composition of steel dust used in tests / wt. %**

Zn	Pb	Cd	Fe	H_2O
22,1	2,2	-	31,5	-

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Table 2 **Characteristics of anthracite dust**

Heating value / MJ/ kg	Ash content / wt. %	Moisture / wt. %	Sulphur content / wt. %	Volatile mat. /wt. %
21,3	24,8	3,8	1,09	5.9

EQUIPMENT AND METHODOLOGY

The entire scope of the study included three stages:

- Determination of the phase composition of steel dusts.
- Determination of the properties of the used carbon-bearing materials.
- Tests of steel dust processing in a rotary kiln.

The investigation of the phase composition of the steel dust was carried out with the use of a PANalytical Empyrean x-ray diffractometer with filtered cobalt radiation with a configuration with a Pixcel detector. The identification of phase composition was carried out per the accredited M1-RTG procedure "Phase identification" (seventh edition of 13th July 2018) and the International Centre for Diffraction Data PDF-4+ base, 2020 edition.

The research on the processing of zinc-bearing materials with the use of an alternative reducer was carried out in a rotary kiln with a length of 2 000 mm, external diameter of 420 mm, internal diameter of 240 mm and a volume of 0,09 m^3.

The kiln was rotating at 0,5 to 0,75 revolutions per minute and tilted by 2° from the level. The kiln diagram is shown in Figure 1. The kiln was fired with natural gas. Before the tests, the rotating drive was started and the furnace was heated to 1 200 °C, and then the feedstock mixture was introduced into the furnace at a rate of 7 kg/h. The temperature in the reduction zone was maintained within the range of 1 473-1 523 K. The dust that was lifted together with the gases was deposited in the process gas discharge system and in the cooler.Process waste was collected in the lower part of the kiln. All products of the process were analysed for the content of: Zn, Pb, Cd and Fe. This analysis was carried out using the AAS method. The weight of steel dust processed in one test was 10 kg.

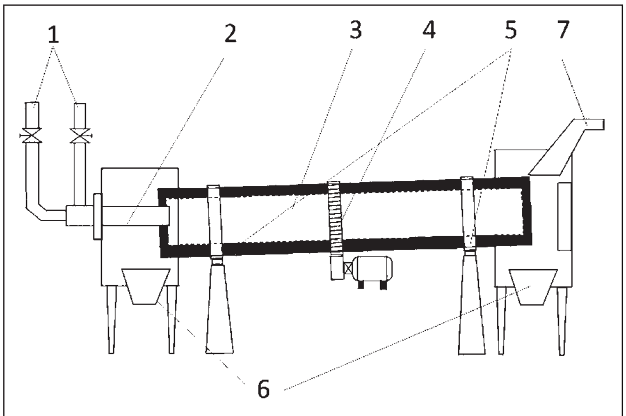

Figure 1 Diagram of the rotary kiln used in the research. 1 - Natural gas and air supply, 2 - burner, 3 - rotary furnace, 4 - furnace drive, 5 - rollers enabling rotary movement, 6 - hoppers (return, torch cut details), 7 - process gas collection system.

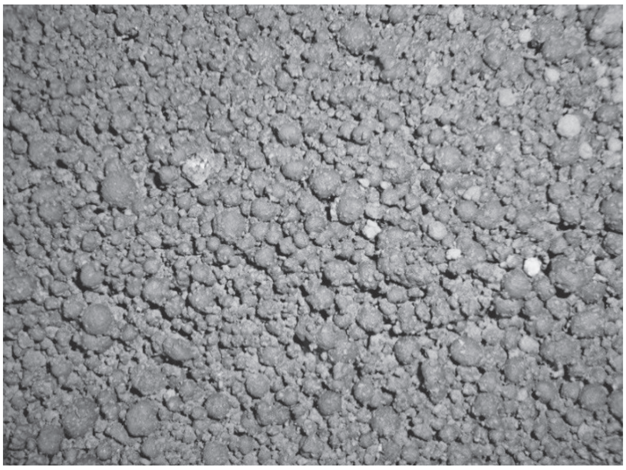

Figure 2 Sample of zinc-bearing feedstock after the pelletisation procedure.

Table 3 **Characteristics of mixtures used in the study (reducer additive 40 %)**

Test No.	Additive SiO_2 / %	Calcium additive / %	Feedstock form
1	-	-	fine
2	0,5	-	
3	-	0,5	
4	0,5	0,5	
5	-	-	Agglomerate
6	0,5	-	
7	0,5	2	
8	-	2	

The research on the processing of zinc-bearing materials in the rotary kiln was carried out in two stages. In the first stage, tests were carried out using the feedstock in a 'loose' form without initial agglomeration of the feedstock material. In the second stage, the material was pelleted using a counter-rotating Eirich R02.r intensive mixer. Due to the appropriate design, this device enables pelletisation of dry mixtures with the addition of water for caking. The main working element of the device is a rotating bowl, inclined to the level, and an eccentrically mounted rotor. A photograph of the pellet obtained from zinc-bearing mixtures is shown in Figure 2.

Table 3 presents the compositions of the feedstock mixtures used in the study.

TEST RESULTS AND OVERVIEW

The studies conducted on the phase composition of the processed steel dusts showed that their basic components are ZnO zincite and Fe_3O_4 magnetite. In addition, the presence of halite, quartz, red lead, CaO oxide, etc. was found [11, 12].

Table 4 summarises the chemical composition of raw zinc oxide obtained in the process of steel dust processing for individual tests.

The zinc content in the obtained slag after the processing of the non-agglomerated feedstock material was

Table 4 **Chemical composition of raw zinc oxide obtained in the process**

Test No.	Content / wt. %			
	Zn	Pb	Cd	Fe
1	35,21	7,12	0,11	0,19
2	36,19	2,54	0,07	0,13
3	35,6	26,49	1,67	0,39
4	40,09	18,97	0,32	0,18
5	51,87	13,75	1,11	0,21
6	53,21	10,82	1,43	0,19
7	54,11	12,21	1,21	0,18
8	54,32	15,12	1,39	0,18

at the level of 2,7 to 9,1 wt. %. In the case of the processing of pelleted materials, the zinc content in the slag ranged from 0,28 to 1,44 wt. %. This means that the use of a pelletised zinc-bearing material as feedstock to the rotary kiln, firstly, protects the material against the lifting of fine fractions from the working space of the furnace (mechanical gust) and, secondly, at the stage of feedstock preparation, it allows obtaining a homogeneous feedstock material. Moreover, the obtained results of zinc and lead content in the case of processing raw materials in the loosely mixed form indicate that this material was not homogenised. This fact is confirmed by the high variability of the lead content in the final product. This phenomenon does not occur for pelletised materials. The obtained zinc content in the waste slag meets the requirements set by companies processing steel dust, because in industrial conditions the zinc content in the slag is 1 wt. %.

CONCLUSIONS

The obtained high degree of zinc removal in the process of steel dust processing in a rotary kiln (at the level of 80 %) indicates that waste anthracite dust may be an alternative carbon-bearing material for use in the discussed process.

High concentration of zinc in raw zinc oxide (up to 53 %) and low concentration in waste slags (0,3-0,7 %) are obtained mainly during the processing of steel dust subjected to earlier pelletisation with technological additives.

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Note: The responsible translator for English language is Ling House, Poland