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SHORT COMMUNICATION

Air classification of blast furnace dust catcher dust for zinc load reduction at the sinter plant

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Abstract The off-gas discharged from a blast furnace is de-dusted in a first stage by a dust catcher or a cyclone. The separated dust consists mainly of iron and coke. Therefore, most of this dust is recycled in the sinter plant. A higher Zn content of the dust is undesirable because the allowed Zn content in the sinter feed material is limited. The reduction of the Zn content of the dust by a simple process would be helpful in the case of higher Zn content in the blast furnace dust. In classification experiments, it has been demonstrated that the Zn content of the blast furnace dust increases with decreasing particle size. Thus, air classification of the dust can be applied to separate the Zn-enriched fines. By separating a small fraction of fines (about 10–20 %) from the blast furnace dust, a reduction of the mass of Zn in the remaining coarse fraction for recycling in the range of 40–60 % is possible and only 5–10 % of the carbon is lost.

Keywords Recycling · Dust treatment · Zinc separation · Blast furnace residues

Introduction

The blast furnace (BF) process is the most important process in integrated steel mills for the production of hot metal (pig iron). There the iron ore is reduced to metallic iron. The off-gas discharged from the BF, the so-called top-gas, is de-dusted in a first stage by the dust catcher which separates the coarser dust form the top-gas (Lajtonyi 2006; Winfield et al. 2012). Alternatively, cyclones are used in some plants for the first off-gas cleaning step (Craig 2008; Suvorov 2009; Winfield et al. 2013). The final de-dusting is usually achieved in a subsequent scrubber (Streit 2007). In some BFs, especially in Japan and China, fabric filters are used for the second de-dusting stage (Murai et al. 1986; Zhang 2009; Lanzerstorfer and Xu 2014).

For European BFs, the average amount of dust separated in the dust catcher is 18 kg dust per ton of hot metal produced (Remus et al. 2013). The dust collected in the dust catcher consists mainly of iron oxides (15–40 % Fe) and coke particles (25–40 % C) which are fine enough to be carried by the discharged gas (Remus et al. 2013). Minor constituents are calcium oxide, aluminium oxide and silica (Das et al. 2007; Remus et al. 2013; Großpietsch et al. 2001). Therefore, the BF dust is usually recycled to the sinter plant (Hansmann et al. 2008; Skroch and Mayer-Schwinning 2012; Więcek and Mróz 2014) to recycle the valuable components.

However, there is also some zinc in the dust catcher dust. The Zn content is typically in the range of 0.1–0.5 % (Remus et al. 2013). Zinc is an unwanted component in the sinter because it causes operational problems in the subsequent BF. It can form crusts in the upper part of the furnace and accumulates in the lining of the furnace which consequently deteriorates (Stepin et al. 2001; Koros 2003; Malemud et al. 2013; Doronin and Svyazhin 2011). Therefore, the total amount of zinc in the charge of a BF is usually restricted to 100–150 g/t of hot metal produced (Remus et al. 2013). The zinc in the charge of the BF is mainly contained in the sinter (Stepin et al. 2001).

The sources of zinc in the sinter are usually recycling materials. In particular, dusts from the de-dusting of the BF

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and the basic oxygen furnace (BOF) off-gas contain zinc. The sinter plant is not very efficient in removing zinc from the feed material (Lanzerstorfer et al. 2015). Therefore, the zinc content in the feed material into the sinter plant has to be limited according to plant-specific conditions. Processes which reduce the content of zinc in the recycled dust can help to increase the admissible amount of recycled dust.

Asadi Zeydabadi et al. (1997) investigated the leaching of Zn from BF dust using sulphuric acid. Depending on the acid concentration, up to 80 % of the Zn was removed from the dust, while at the same time only about 6 % of the iron was dissolved. However, the drawback of leaching processes is the generation of a liquid effluent which has to be treated.

Jansson and Sundqvist Ökvist (2004) split BF dust by sieving it into six size fractions. The finest fraction was <45 µm, while the coarsest fraction was >250 µm. It was found that the iron content decreases from the finest fraction to the coarsest fraction, while the behaviour of the carbon content is the opposite. The Zn content in the dust fractions was quite constant. The range was 0.16–0.24 %. Only in the coarsest fraction, the Zn content was less (0.09 %).

When a component is enriched in the fine fraction of a dust, classification can be applied to split the dust into two size fractions with a different content of this component. This has been shown, for example, for the dry residue from sinter plant off-gas cleaning (Lanzerstorfer and Neuhold 2015). Air classification was also used to treat the dust collected in a second-stage fabric filter to separate a fine fraction with increased Zn content (Murai et al. 1986; Lanzerstorfer and Kröppl 2014). However, there is no information available regarding the use of air classification for the treatment of dust catcher dust.

The aim of this study was to investigate the application of air classification to reduce the amount of zinc fed to the sinter plant by BF dust recycling (Fig. 1). By air classification, the BF dust would be separated into a coarse fraction with a reduced Zn content and a fine fraction with an increased Zn content. In such a classification, an important parameter to be investigated is the cut size in dependence of the efficiency of the Zn separation. The Zn-enriched fines fraction can be fed to a Zn leaching process or to the BOF. Dust from the dust catcher of the top-gas de-dusting of an industrial BF was separated into several size fractions by air classification. From the results of the

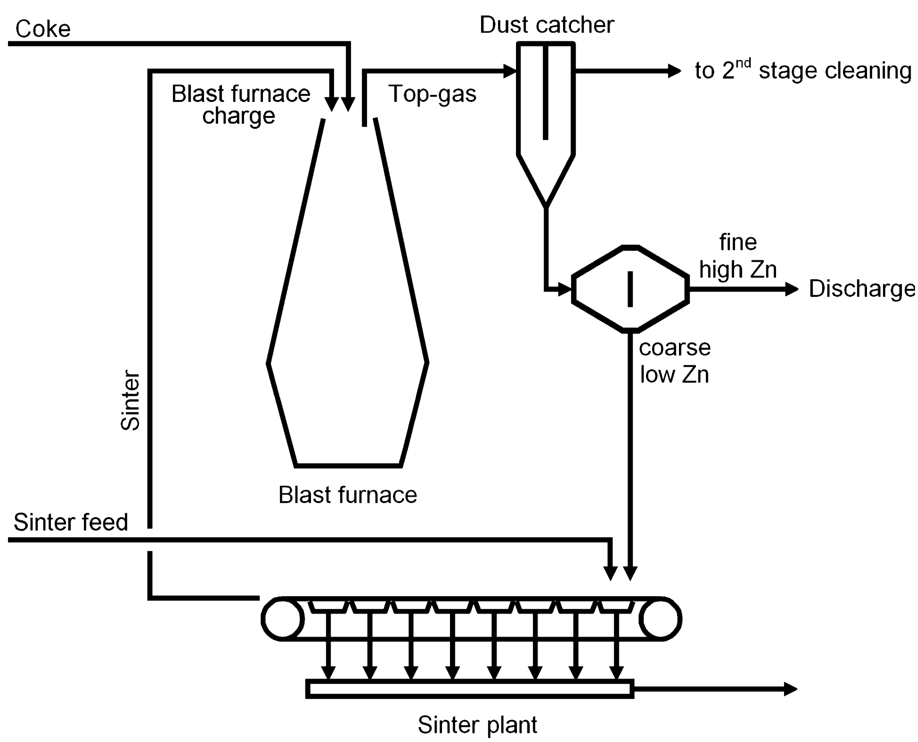

Fig. 1 Flow sheet for BF dust recycling applying classification

chemical analysis of the size fractions, the elimination efficiency of the classification process for zinc at various recycling rates was calculated.

The work was carried out in spring 2015 at the University of Applied Sciences Upper Austria, Wels Campus.

Materials and methods

Dust sample classification

The dust sample investigated was collected from the dust catcher of the top-gas cleaning system of an industrial BF. Approximately 2 dm^3 of dust was taken from the dust discharge. For dry classification, a laboratory classifier 100 MZR from Hosokawa Alpine was used. The classification procedure is described in detail elsewhere (Lanzerstorfer and Kröppl 2014). The speed of the classifier in the four classification runs was 21,000, 11,000, 6,000 and 3,000 rpm. Thus, the dust was split into five sized fractions.

Sample analysis

The volume of the classified samples was reduced to a volume suitable for the analysis using a Quantachrome Micro Riffler sample divider. The moisture content of the dust samples was measured gravimetrically using a MA35M infrared moisture analyser from Sartorius. The particle size distribution of the dust samples was measured using a HELOS/RODOS laser diffraction instrument with dry sample dispersion from Sympatec. The samples were digested in concentrated boiling HCl for 2 h. The digestion procedure was similar to that used by Leclerc et al. (2003); only the digestion time was longer. After dissolving samples, the concentration of Zn was determined by flame atomic absorption spectrometry. The concentration of Fe was determined in the dissolved samples after reduction of Fe^{3+} with Sn(II)-chloride by potentiometric titration according to Zimmermann–Reinhardt. The total carbon (TC) content of the dust catcher dusts was determined using a LiquiTOC system with a Solids Material extension from Elementar Analysensysteme.

Results and discussion

Characterization of the dust catcher dust

The moisture content of the dust was 1.2 %, the Fe content was 39.4 %, and the TC content was 28.2 %. Compared to the literature data for BF dust, the investigated dust is relatively high in Fe content and low in TC content (Remus et al. 2013). The Zn content of the dust was 0.52 %. Thus, the Zn content is at the upper limit of the range described in the literature (Remus et al. 2013). The mass median diameter of the dust was 130 μm.

Classified dust catcher dust

The cut size of the first, second, third and fourth classification runs was 2.1, 4.5, 9.2 and 32 μm, respectively. The

Table 1 Particle classes produced from the BF dust sample

	Mass fraction in %	x_{10} in μm[a]	x_{90} in μm[a]	Fe in g/kg	Zn in g/kg	TC in g/kg
Particle class 1	4.3	0.54	3.75	234	36.0	138
Particle class 2	5.1	2.29	8.64	329	15.2	132
Particle class 3	6.9	3.49	17.4	375	9.93	133
Particle class 4	15.8	10.4	36.4	444	4.63	150
Particle class 5	67.9	29.2	214	393	2.07	349

[a] x_{10} is the particle size with 10 % of the mass of the material consisting of particles smaller than this size and the remaining mass of the material consisting of larger particles. x_{90} is defined in a similar way

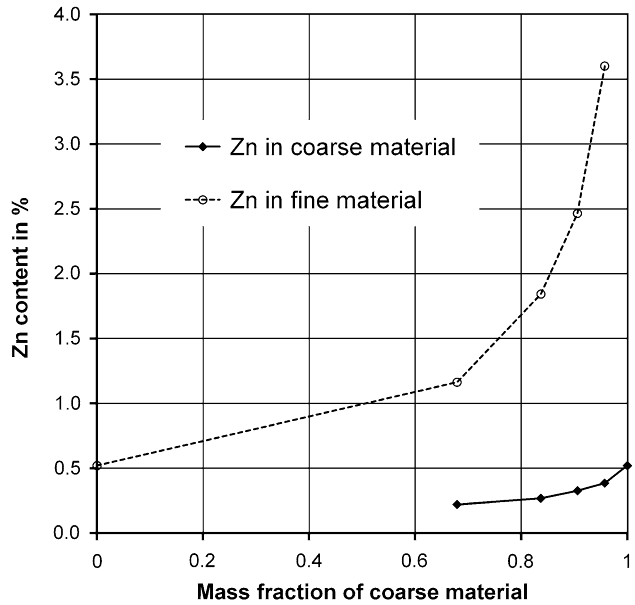

Fig. 2 Zn content in the coarse material and in the fine material as a function of the coarse material fraction

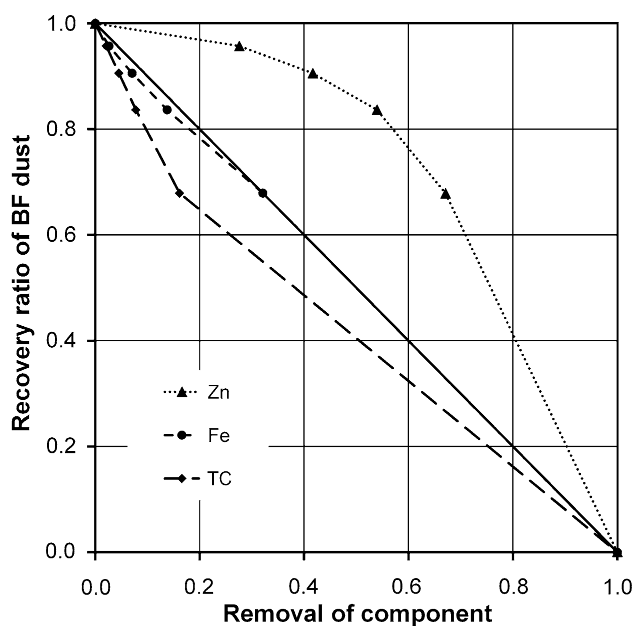

Fig. 3 Recovery ratio of BF dust as a function of the removal of various components

mass fractions of the five BF dust particle classes produced and their size ranges are summarized in Table 1. The content of Zn, Fe and TC in the various particle classes is also shown in Table 1.

Fe is the main component in the BF dust. From particle class 1 to particle class 4, the Fe content increases with increasing particle size, whereas in the coarsest particle class the Fe content is lower. The Zn content is highest in the finest particle class and is approximately halved from particle class to particle class. For the finer particle classes, the carbon content is constantly low, while in the coarsest particle class it is more than twice as high.

The Zn content calculated for the coarse material and the fine material as a function of the coarse material mass fraction is shown in Fig. 2. The terms coarse material and fine material refer to the two fractions of material obtained by classification of the BF dust in a process with similar separation characteristics as the air classifier used in the experiment. The calculations required to obtain such a diagram from the classification experiments are described elsewhere (Lanzerstorfer 2015). When only the finest material is separated by classification, the mass fraction of the remaining amount of coarse material for recycling is only reduced slightly. The reduction of the Zn content in the coarse material is considerable, and the Zn content in the fine fraction is high. With decreasing coarse mass fraction, the Zn content decreases continuously, for both the remaining coarse fraction and the fine fraction.

Recycling of classified BF dust

The mass flow rate of Zn to the sinter plant caused by the recycling of air classified BF dust is a function of the mass fraction of the coarse material as well as the Zn content of the coarse fraction. In Fig. 3 this connection is shown. For instance, about 40 % of the Zn can be removed with the finest 10 % of the BF dust separated by air classification. The removal rate for Fe and TC is below the removal rate for the total mass of the BF dust because these components are depleted in the fine fractions. The calculated curve is therefore below the neutral line connecting the points (1/0) and (0/1).

The results show that air classification would be an effective method to reduce the recycling of Zn to the sinter plant. The coarse fraction is depleted in Zn and enriched in TC, while the Fe concentration is nearly unchanged. A small fraction of fines has to be discharged. As the Zn content is still relatively low (2–3 %), recycling via the BOF could be considered.

Conclusion

Recycling of the BF dust separated in the dust catcher or cyclone to the sinter plant is the state of the art for the utilization of this residue. However, an increased Zn content of the recycled dust is undesirable because of the plant-specific limits for the Zn content in the sinter feed material. Therefore, processes which reduce the Zn content of the recycled material can help to increase the recycling rates, especially in the case of a higher Zn content of the dust. In the experiments, it has been demonstrated that air classification would be an effective method for the treatment of BF dust. By separating a small fraction of fines (about 10–20 %) from the BF dust, a reduction of the mass of Zn in the coarse dust recycled to the sinter plant in the range of 40–60 % is possible. The loss of TC would be only approximately 5–10 %.

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