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Air classification of blast furnace dust collected in a fabric filter for recycling to the sinter process

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ABSTRACT

Totally dry cleaning has become a common technology for top gas cleaning in blast furnaces in recent years. A significant advantage of totally dry gas cleaning is that the dust collected is obtained as dry powder, thus simplifying the recycling of the dust in the sinter plant and avoiding aqueous emissions. The concentration of some heavy metals, especially zinc, in the collected dust is usually higher than the maximum tolerable concentration for recycling to the sinter process. Therefore, a process for separation of dust with a low level of contamination from the rest is necessary to make partial recycling possible. This is possible because the limited components are more volatile and accumulate in the finer dust fraction. In wet blast furnace top gas cleaning, hydrocyclones are well established for this separation. For the separation of dry powder from the dry dedusting process air classification can be used. Dust from the top gas of a blast furnace with a fabric filter for dry top gas cleaning was split into several size fractions using a laboratory air classifier. The concentration of Ca, Cd, Cl, Cu, Fe, K, Na, Pb and Zn was analysed for each particle class and the loss on ignition was determined. A strong dependence of the concentration on the particle size was found for the more volatile metals, whereas the Fe and Ca concentration and the loss on ignition were quite evenly distributed. With the calculated recovery–removal-functions the possible recycling rate can be estimated for a given removal rate for the limited components.

1. Introduction

In integrated steel mills the blast furnace is the most important element for the production of hot metal (pig iron). The top gas (off-gas) of a blast furnace contains carbon monoxide and hydrogen. The resulting calorific value makes this gas a fuel for blast furnace stoves, boilers and other burners. For trouble-free operation of these burners a low dust concentration is required in the clean top gas. Typically, dust separation is performed in two stages. First, the coarse dust is collected in a dry dust separator (dust catcher). In a second separation step the remaining fine dust is collected, resulting in a dust concentration of less than 10 mg/N m^3 in the clean top gas (European IPPC Bureau, 2012). The second dust separation step is usually performed by a scrubber system, where most of the scrubber water is recycled after separation of the collected dust particles from the scrubber water by means of sedimentation. The coarse dust from the dust catcher and the sludge from the sedimentation are rich in iron and carbon. Recycling of this material in the production process is therefore desirable. However, there are also unwanted components in the dust, such as zinc, lead and alkali metals. The typical composition of the residues from blast furnace top gas cleaning is shown in Table 1. The mass median diameter of the coarse dust is typically in the range of 100–200 μm (El-Hussiny and Shalabi, 2010; Leimalm et al., 2010). The grain size of the sludge is smaller, with a mass median diameter of 25–40 μm (Uno et al., 1979; Van Stein Callenfels, 2004).

The material flows around the blast furnace and the sinter plant, the main recycling location for fine grained material in integrated steel mills, are illustrated in the simplified process flow diagram below (Fig. 1). Recycling of the coarse dust or sludge back to the blast furnace is not possible, even though both residues are rich in carbon and iron. The reasons for this are the small grain size and the zinc content. An increased amount of zinc in the charge of the blast furnace can cause operational problems in the blast furnace. Zinc 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). Zinc also forms a circuit inside the blast furnace by evaporation of the zinc in the lower part of the furnace, upward flow of the zinc vapour with the blast furnace gas, condensation of most of the zinc on the surface of the burden material which carries the zinc downwards, while only a

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Table 1
Composition of coarse dust and sludge from blast furnace top gas cleaning (European IPPC Bureau, 2012).

Component	Concentration in the coarse dust in % (w/w)	Concentration in the sludge in % (w/w)
C	24–40	15–47
Fe	15–40	7–35
Ca	1.4–5.7	2.5–13
Zn	0.1–0.5	1–10
Pb	0.02–0.07	0.8–2.0
Na	0.02–0.47	0.11–0.18
K	0.20–0.80	0.07–0.30

fraction of the zinc leaves the furnace with the top gas. This circuit results in increased coke consumption (Das et al., 2007). Therefore, the total amount of zinc in the charge is usually restricted to 100–150 g/t of hot metal produced (European IPPC Bureau, 2012). The zinc in the charge of the blast furnace is mainly contained in the sinter, which is produced in the sinter plant from fine-grained iron ore, coke breeze and internal recycling fines like dust, sludge and mill scale (Stepin et al., 2001).

Only a small fraction of the zinc fed is volatilized in a sinter plant. Therefore, blending of the sinter plant feed material must keep the zinc concentration in the sinter feed below 200 g/t (European IPPC Bureau, 2012). The well-established recycling of the sinter dust back to the sinter feed further limits the de-zincing ability of the sinter plant. Material with a higher zinc concentration usually has to be rejected (Dolinskii et al., 2010). The coarse dust from the dust catcher can be returned to the sinter plant in most steel mills because of the relatively low zinc concentration. The high zinc content of the sludge is often an obstacle to recycling (Das et al., 2007; Großpietsch et al., 2001). Worldwide, only about 40% of the estimated total amount of 13 million tons per year of blast furnace sludge is recycled to the sinter process (Hansmann et al., 2008). According to Makkonen et al. (2002), about 7700 t per year of blast furnace sludge cannot be recycled in one Finnish steel mill and in another steel mill that uses a dry electrostatic precipitator for second-stage blast furnace top gas cleaning, about 3000 t per year of second-stage blast furnace dust cannot be recycled.

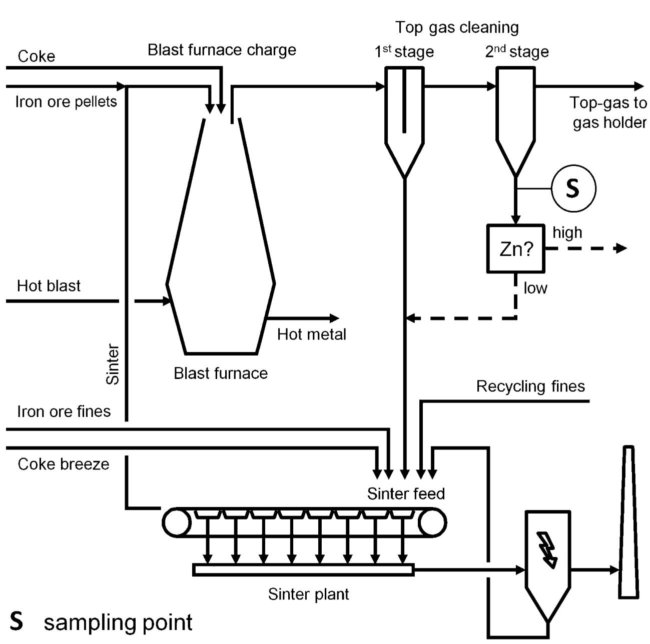

Fig. 1. Simplified process flow diagram of a blast furnace and sinter plant.

As demonstrated by Zeydabadi et al. (1997), Van Herck et al. (2000) or Vereš et al. (2012), the zinc concentration in the residue can be reduced by hydrometallurgic processes. However, such complicated hydrometallurgical processes are not applied commonly in the steel industry. For separation of the sludge from wet top gas cleaning into a fraction with low contamination for recycling and the rest for discharge, classification using hydrocyclones is well established in many steel mills (Uno et al., 1979; Butterworth et al., 1996; Großpietsch et al., 2001; Van Stein Callenfels, 2004; Korpa and Mudron, 2006). Separation by classification is possible because zinc is evaporated in the belly and the bosh of the blast furnace and condenses when the gas cools down in the furnace shaft. Assuming that the zinc content of the dust all comes from the condensation of zinc vapour, the zinc concentration of dust particles would be proportional to the specific surface area of the particles and therefore inversely proportional to the particle diameter (Ma, 2008).

Recently, totally dry cleaning using fabric filters has become established as a common technology for top gas cleaning in blast furnaces (Zhang, 2009; Craig et al., 2012). In such systems a fabric filter replaces the wet scrubber of the second dedusting stage. Besides other advantages, one major advantage of the totally dry gas cleaning is that the collected dust is obtained as dry powder. Thus, storage and handling of the dust material is quite simple and there is no water in the residue, which would usually have to be removed prior to recycling. For separation of the dry dust collected in a filter into a low-contaminated fraction for recycling and a highly-contaminated fraction for discharge, an air classification process can be used. The first results of air classification of dust collected in a fabric filter for dry second-stage dedusting of blast furnace top gas were presented by Murai et al. (1986). The separation efficiency reported for Zn was slightly improved compared with the results obtained for classification of the sludge from wet second-stage dedusting with hydrocyclones.

The aim of this work is to investigate the concentration of Zn and several other heavy and alkali metals in the dust from second-stage dry top gas cleaning as a function of the size of the dust particles. For this purpose a laboratory classifier was used to separate a dust sample into several size classes. These were then analysed to identify their components. Knowledge of the relationship between particle size and the concentration of various components will facilitate partial recycling of filter dust from second-stage dry top gas cleaning of blast furnaces.

2. Material and methods

2.1. Dust sample

The sample of about 2 dm^3 of blast furnace dust was obtained from the discharge of the fabric filter system for dry dedusting of blast furnace top gas. This system is installed downstream of a dust catcher. The sampling location for the dust is indicated with S in Fig. 1. The volume of the dust sample was reduced to a volume suitable for the various measurements using sample dividers (Retsch PT100 and Quantachrome Micro Riffler) which were applied repeatedly. The particle size distribution was measured using a laser diffraction instrument with dry sample dispersion from Sympatec, type HELOS/RODOS.

2.2. Classification of the dust sample

A laboratory classifier 100 MZR from Hosokawa Alpine was used for dry classification of the dust sample. The procedure for the classification is illustrated in Fig. 2. In the first classification step, the finest dust fraction was separated from the mixture and collected in the cyclone at the outlet of the classifier as Particle Class 1. The