DUST RECYCLING IN INTEGRATED STEEL MILLS: REDUCING ZINC RECIRCULATION

[1]Christof LANZERSTORFER

[1]*University of Applied Sciences Upper Austria, Wels, Austria, EU,*
c.lanzerstorfer@fh-wels.at

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Abstract

Considerable amounts of Fe-containing fine dusts are generated in an integrated steel mill, mainly at the blast furnace (BF) and the basic oxygen furnace (BOF). Limitations in dust recycling via the sinter plant arise especially from the limit for Zn in the BF feed. Therefore, dust with an elevated Zn content is usually discharged to landfill, resulting in considerable losses of Zn. In this study the possibilities for increased internal dust recycling in integrated steel mills by implementing air classification of dusts are discussed. The aim of this concept is to avoid landfill of steel mill dust by recycling of the Fe in the steelmaking process while producing a Zn-enriched by-product that can be utilized in secondary Zn production. Since the distribution of Zn in the dusts is not even but depends on the size of the particles, air classification can be applied to separate dusts into a coarse Zn-depleted size fraction and a Zn-enriched fine fraction. Low-Zn content coarse fractions of the dusts can be recycled in ironmaking, medium-Zn content dust fractions could be recycled in steelmaking, where the Zn input is not as limited as in ironmaking and Zn-rich fine dust fractions with a Zn concentration high enough for use in secondary Zn production could be recycled there.

Keywords: Integrated steel mill, dust recycling, zinc

1. INTRODUCTION

In integrated steel mills the production of steel involves two main steps: in a first step iron is produced based on the processing of iron ore (ironmaking). In a second step the liquid iron is converted into steel (steelmaking). In ironmaking usually two process units in series are needed, the sinter plant and the blast furnace (BF). The BF provides the liquid iron or hot metal by reducing the iron ore into metallic iron. In the sinter plant fine grained iron ores are agglomerated together with fluxes and iron-rich in-plant return fines to sinter as charge material for the BF. In steelmaking steel is produced in the basic oxygen furnace (BOF) by removal of the dissolved carbon from the liquid iron by blowing oxygen onto the liquid bath. The heat of this exothermic reaction is used to melt the cooling scrap, which is charged into the converter together with the liquid iron [1].

In all three process units, considerable amounts of dust-containing off-gases are produced. The off-gas from the processes has to be dedusted in a so-called primary dedusting system before it can be released to the atmosphere in case of the sinter off-gas [2] or before it can be used as fuel in case of BF top gas and BOF off-gas [1]. For the dedusting of BF top gas and BOF off-gas often two-stage dedusting systems are applied, where the coarse dust is separated from the off-gas in the first dedusting stage and the fine dust is separated in the second stage [3]. Additionally, dust has to be separated from the shop ventilation air in so-called secondary dedusting systems. These are the room dedusting system of the sinter plant, the cast-house dedusting of the BF and the secondary dedusting system of the BOF shop. For dedusting in steel mills dry dedusting systems are increasingly used. However, in BF and BOF primary dedusting also wet systems are still common.

The residues from dedusting are finely granular materials, which contain iron as the main component. However, the dusts also contain other components. An important element contained in the dusts is Zn. Some

Zn enters the steel mill with the iron ore as a minor constituent. Higher amounts of Zn are often contained in the cooling scrap. Therefore, the level of Zn can be higher in the BOF dust compared to the BF dust or sinter dust. The liquid steel and the slags contain a minimal amount of Zn. Therefore, Zn that enters the process has to leave the steel mill mainly with the dusts. [4]

The aim of this work is to discuss how dust recycling can be optimized by applying classification of the residues to reduce Zn recirculation.

2. DUST RECYCLING IN INTEGRATED STEEL MILLS

The dusts and sludges which result from off-gas dedusting in ironmaking and steelmaking are usually utilized by recycling to the feed of the sinter plant. However, especially Zn is an unwanted component in the feed material to the sinter plant because it causes operation problems in the subsequent BF. The typical limit for Zn in the charge of the BF 100 - 150 g/t of hot metal produced [1]. Therefore, dusts with a higher Zn content often have to be excluded from recycling and are discharged to landfill sites. If the zinc content of a residue is very high it can be sent to pyrometallurgical processing [5,6], for example in a Waelz kiln, for subsequent recovery of Zn in secondary zinc production. However, this is more usual for dusts from EAF steelmaking, because the zinc content of EAF dust is significantly higher [1,7].

An alternative way of utilization of dust with a higher Zn content in an integrated steel mill is charging it into the BOF after agglomeration by briquetting or pelletizing [8,9]. To limit the amount of sulfur fed to the BOF the agglomerates can be charged into the deS station [10].

Figure 1 shows an overview of the dust and sludge recycling paths in an integrated steel mill. The black solid flow lines show the typical flow of the dedusting residues, while the grey solid lines represent the recycling of agglomerated BOF dedusting residues back into the furnace, which is in use in some steel mills. The dashed lines show the flow lines of an optimized recycling concept applying air classification.

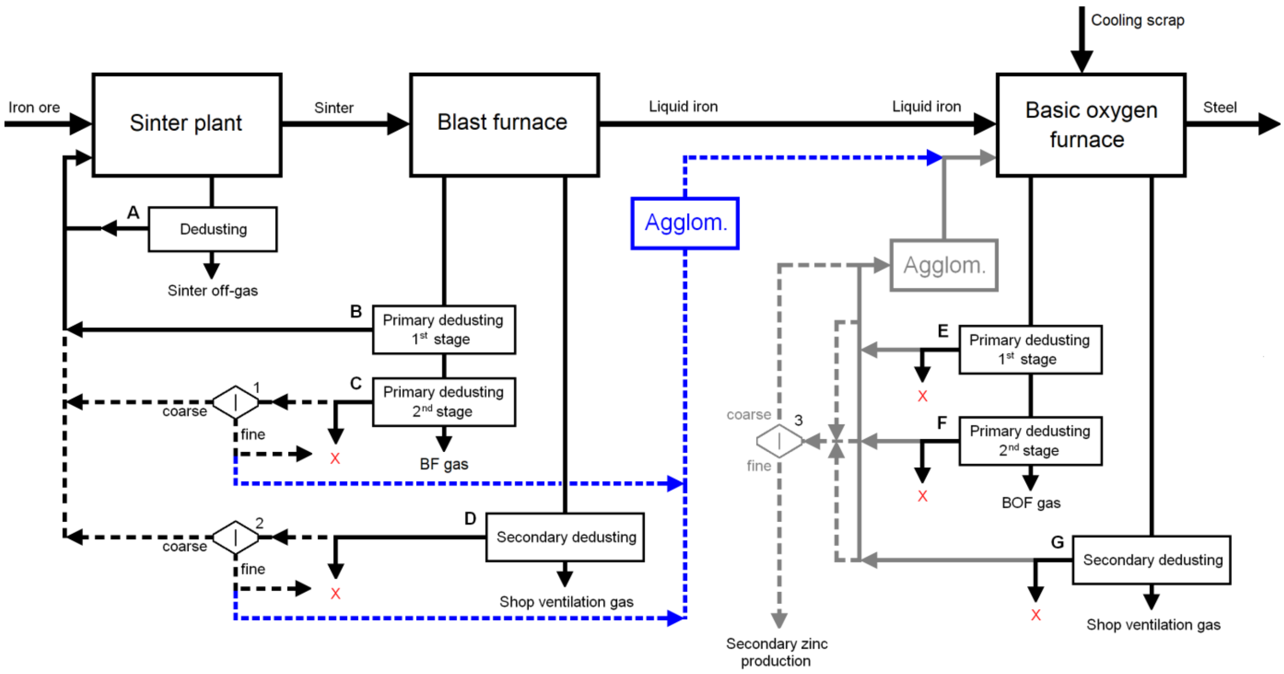

Figure 1 Process flow diagram for an upgraded internal dust recycling in integrated steel mills; left side: ironmaking; right side: steelmaking

The dust from the sinter plant (A) is recycled in most sinter plants [1,11]. Its Zn content is rather low because of the process conditions in the sintering process where Zn contained in the ore is scarcely volatilized [12].

The BF dust from the first dedusting stage of the primary BF dedusting system (B) can usually be recycled via the sinter plant because of its low Zn content. In contrast, the recycling of the residue from the second stage dedusting (C) is limited often by the Zn content [1,13,14] and therefore is sent to landfill (X). In case of a wet dedusting system hydrocyclones (1) are applied in some BF plants to recover a coarse, zinc-depleted fraction of this sludge for recycling [15,16]. If a dry dedusting system is applied the use of air classification has been suggested [17,18] for the same purpose. The residue from the BF secondary dedusting system is mostly recycled to the sinter plant but sometimes it has to be sent to landfill (X) [19,20].

The dust or sludge from the BOF primary 2nd stage (F) and secondary off-gas dedusting (G) systems is often discharged to landfill (X) [13,14] because of its Zn content, while the dust from the primary 1st stage dedusting system (E) can be recycled via the sinter plant (Y). In few BOF plants the residues are recycled back into the BOF (D) after agglomeration by briquetting or pelletizing [1,8,9,21]. In these plants recycling serves to increase the Zn concentration of the BOF dust. When the concentration has reached a certain limit the dust or sludge is sent to landfill or it is processed for Zn recovery in external plants. The amount of dust which has to be discharged is thereby reduced since the amount of Zn in the dust is defined by the amount that enters the steel mill.

A disadvantage of recirculating Zn-containing material in pyrometallurgical processes is the increased consumption of energy and reduction agent because the volatilization of Zn takes place via the reduction to metallic Zn. When the Zn vapor is oxidized and re-condensed in the off-gas system the reaction enthalpy is released there thus increasing the off-gas cooling requirements. Therefore, the number of cycles a Zn atom has to go through before it leaves the steel mill has should be minimized.

3. OPTIMIZEED DUST RECYCLING FOR REDUCED ZINC RECIRCULATION

The Zn concentration of different size fractions of a BF dust or a BOF dust significantly depends on the size of the particles [18,22-24]. The results of recent studies are summarized in **Figure 2**. This dependence is also the basis for the application of hydrocyclones to split the BF sludge into a coarse Zn-depleted fraction and a fine Zn-enriched fraction.

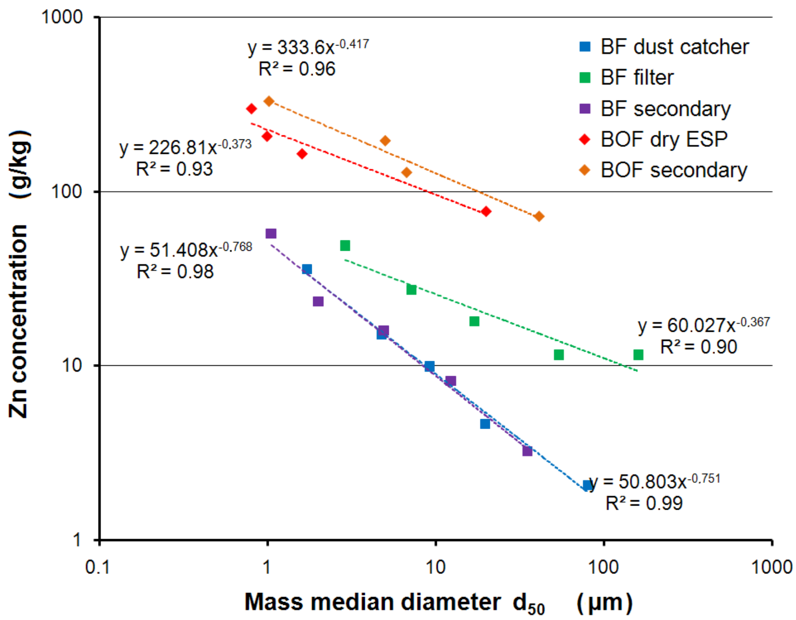

Figure 2 Size dependence of the Zn concentration of various steel mill dusts

Currently, Zn enrichment by classification is applied only for the treatment of BF sludge. However, according to the results summarized in **Figure 2** classification could also be used for the treatment of other dedusting residues to increase dust recycling and reduce Zn recirculation. In the case of dry dedusting residues air classification would be a suitable method. Sieving in not applicable because of the fineness of the dusts.

For sustainable production the iron should be returned into one of the ironmaking or steelmaking processes. The most suitable point for recycling of carbon is the sinter plant or the BF. The Zn should be used in secondary Zn production. For this external utilization a high Zn content of the discharged residue is favorable.

In the proposed upgrade the currently discharged dedusting residues with a medium zinc content - marked with an X in the flow diagram **Figure 1** - would be air-classified into two size fractions each. In the ironmaking section (**Figure 1**, left side) the low-zinc content coarse fraction could be recycled via the sinter plant (**Figure 1**, black dashed lines). The zinc-enriched fine fraction would be transferred to the steelmaking section (**Figure 1**, right side, blue dashed lines), where the zinc input is not as limited as in the ironmaking section. The agglomerates containing these dusts might be introduced into the desulfurisation unit of the BOF plant in order to avoid increased sulfur input into the BOF. The dusts from the BOF would also be air-classified. The zinc depleted coarse fraction would be recycled into the BOF, while the zinc enriched fine fraction could be sent to secondary zinc production (**Figure 1**, grey dashed lines).

Air classification of the dusts from the ironmaking process has been proposed to split the dusts into two size fractions: a Zn-poor coarse size fractions and a Zn-enriched fine size fraction [18,22,24]. Thereby, the amount of recycled Zn can be reduced or the amount of recycled dust can be increased at a constant amount of Zn in the recycled dust. This system could be extended by applying air classification also to steelmaking dust. For optimized operation of the classification unit on-line Zn measurement [25] of the produced size fractions could be used to control the operation of the air classifiers.

4. CONCLUSION

Utilization of fines for off-gas dedusting in integrated steel mills can be increased by the use of air classification. This is because the Zn concentration in the dusts depends on the particle size. Regardless of the Zn content of the dusts, the fine fractions of the dusts are Zn-enriched. Thus, air classification can be applied to produce Zn depleted and Zn-enriched fractions, which enables optimization of the recycled dust mass flows.

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