Maximising Metal Recovery from Incineration Ashes

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Abstract

In a three year project – funded by BMBF – seven partners develop a new concept for the metal recovery from incineration ashes. In Germany the potential of unrecovered nf-metals from incineration ashes is approximately 108.000 Mg/a. Up to now less than 30 wt.-% of the contained nf-metals are separated, so that the available resource potential is barely exploited. Hence the nf-metal content of the fine-grained fractions below 10 mm are not recovered. The project is based on a holistic approach of enhanced and new developed processing techniques and selective metallurgical steps.

The iterative optimisation of nf-metal recovery from fine- and coarse-grained incineration ashes will be validated by the operation of a pilot scale sorting plant. The conditions for the sorting, but also the process window of the pyrometallurgical processes will be defined by laboratory scale trials. The approach combines the application of optimised eddy current separation and X-ray transmission sensor technology which enables separation in light (Al) and heavy metal (Cu, Zn) concentrates or even alloys.

Melt experiments followed by the chemical analysis of the products have three functions: first function is the conclusion upon separation criteria, second is the investigation of pyrometallurgical recycling methods especially for fine-grained metal concentrates and third is the identification of interfaces for closing the loop of valuable metals.

The full paper will be published soon after the conference in a scientific journal.

1 Introduction

Incineration becomes the main disposal route for mixed municipal solid waste (MMSW) in Germany. Since 2005 disposal of untreated waste is no longer permitted, so nowadays about 70 % of

MMSW is treated thermally [1]. The main solid residue from MMSW incineration is bottom ash with an amount of about 4.8 million Mg/a, which is still tendentially increasing [2]. The products of state-of-the-art bottom ash treatment facilities are mineral fractions, unburned materials, ferrous and non-ferrous metals. The main component of bottom ash is a mineral fraction (85-90 wt.-%) which is used for underground disposal and as a building material for road or landfill construction. Unburned materials (1-5 wt.-%) are returned to incineration. The most valuable fractions are the ferrous (fe) and non-ferrous (nf) metals which have a share of 7-10 wt.-%. [3] [4]

2 The VeMRec Project

VeMRec is an acronym and can be translated as “Loss-minimised recovery of nf-metals from bottom ash with sensor-based sorting technology”. This joint venture project is part of the German public funded framework initiative “r3 – Strategic metals and minerals – Innovative technologies for resource efficiency”. One goal of the VeMRec project is to optimise the recovery of nf-metals from the anthropogenic resource bottom ash with regards to the complete value chain.

Maximising nf-metal recovery with existing treatment technology is one major issue of the project. In established treatment facilities up to 90 % of nf-metals are lost in the fine fraction. Due to inefficient processing the potential of nf-metals in the coarse-grained fraction is not exhausted either. Within the project one treatment facility will be optimised due to a high nf-metal recovery rate. These optimisations are accompanied by mass balances and sampling.

To meet criteria for metallurgical routes, further processing of the nf-metals separated by the existing bottom ash treatment facility is required. These materials are treated in a pilot-plant under various process configurations. The pilot process contains different functional elements. One important step is an impact mill which stresses the material due to the separation of adhering and incorporated mineral composites. These mineral components are crushed to a fine fraction during the impact mill process, whereas the nf-metals do not experience a size reduction. Afterwards most of the mineral fine-fraction can be removed from the process by screening.

With a second screen the material is classified into different grain sizes in order to fulfil the specifications of an X-ray transmission (XRT) sorting system. According to density classification the XRT separator ejects a heavy metal fraction while a light metal fraction is passed through. The former consists of copper, brass and other heavy metals. Due to the fact that several configurations can be altered, processing parameters and functional elements can be varied and therefore investigated.

The subsequent step of metallurgical treatment needs to be distinguished between light metal recycling and the recovery of heavy metals. For the light fraction there are two opportunities, remelting without application of molten salt or refining with salt as collecting reagent for oxides and other impurities. The industrial pyrometallurgical recycling of heavy metal fractions is conceivable in a top submerged lance furnace or top-blowing rotary converter.

3 Methodology

The nf-metals, which are recovered from bottom ashes according to the state-of-the-art, are tested in four steps in order to receive detailed material information (see Figure 1). These steps consist of test sieving for particle size distribution, grain splitting with humidity analysis, magnetic separation for the removal of ferromagnetic materials and state-of-the-art eddy current separation for enhanced screening of nf-metal content. After this testing procedure X-ray transmission sorting is applied to the pre-treated nf-metals with a first set-up for throughput and separation density. In lab-scale trials the light and heavy metal fractions are molten and first results for the composition of melting products are obtained by optical emission spectrometer (OES).

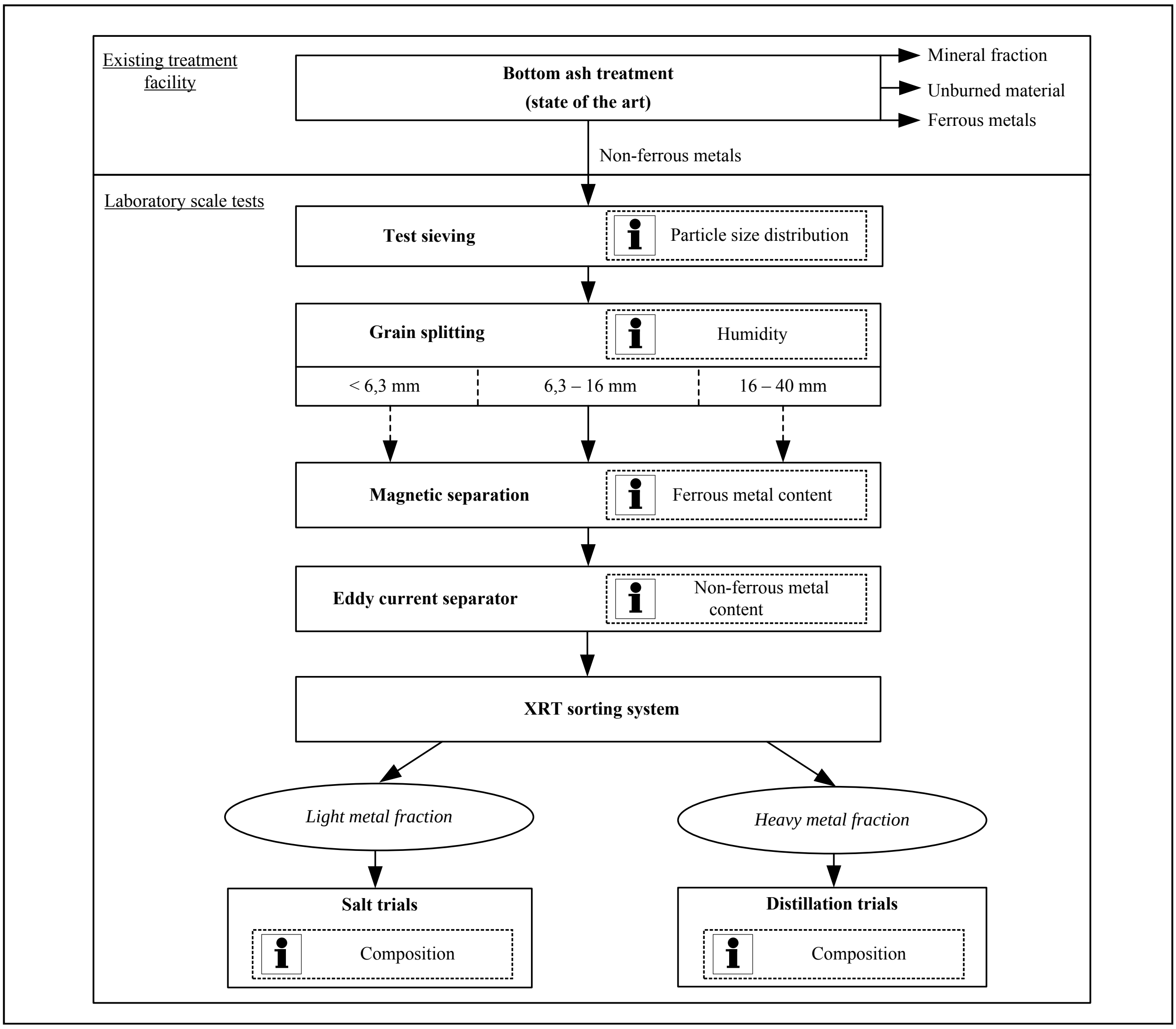

Figure 1: Methodology of the applied sample analysis for nf-metals

The chemical analyses of the melting products allow a first indication for the optimisation of the processing procedure in the pilot plant as well as the pyrometallurgical treatment of sensor-based sorted nf-metal fractions.

The nf fractions of the XRT sorting system visually show a high grade of bulk and surficial contamination with minerals – mainly known as oxides and carbonates – (see Figure 2), since they are not conditioned by the impact mill. For this reason the experimental set-up for light metal recycling is determined as a refining step with an excess of molten salt. For the heavy metal fraction a melting process under a premolten fayalite ($SiO_2 \cdot 2FeO$) slag is investigated besides of vacuum distillation trials accounting the high content of zinc, which origin is assumed to be brass (CuZn alloys).

Figure 2: Unconditioned, sensor-based sorted nf-metal concentrates
a) light metal fraction 6.3-16 mm and b) heavy metal fraction 6.3-16 mm

The metal content of the nf-metal concentrates reached about 70 wt.-% in a preliminary investigation, so that the remaining 30 wt.-% are assumed to be non-metallic inclusions. To depict the complete metal inventory a salt factor of two is applied to the weight fraction of non-metallic inclusions.

The influence of varying NaCl-KCl salt compositions (as of Table 1) on the metal yield and the produced alloy has also been investigated. With higher fractions of NaCl the liquidus increases, so that elevated process temperatures are necessary. For a better comparability the superheating referring to the different liquidus temperatures is kept equal. For promotion of coagulation 3 wt.-% of calcium fluoride is added to the molten salt. Due to the volatile character of nf-metal concentrates every trial is repeated twice so that reproducibility of the results is also verified.

Table 1: Overview of light metal trials in a lab-scale furnace

Feedstock material	**Salt composition [at.-%]**	**Salt factor [-]**	**Temperature [°C]**
Light metal fraction 6.3 - 16 mm; 1.4±0.1kg	NaCl-50KCl + 3 wt.-% CaF_2	2	750
Light metal fraction 6.3 - 16 mm; 1.4±0.1kg	NaCl-30KCl + 3 wt.-% CaF_2	2	800
Light metal fraction 6.3 - 16 mm; 1.4±0.1kg	NaCl-10KCl + 3 wt.-% CaF_2	2	875

4 Results

Following first results of lab scale trials are pointed out. Process variables like salt composition and temperature are focussed within this first trial series. Table 2 summarises the composition of product alloys as well as the melting yield η averaged over nine light metal trials. The variance $\sigma_{relative}$ is equal to the relative deviation of the individual analysis result from the series average μ and therefore indicates the statistical outliers within the trial series.

Table 2: Average composition and melting yield of remolten aluminium fraction 6.3-16 mm

Content [wt.-%]	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Ni**	**Zn**	**Pb**	**Sn**	**η**
μ	95.13	1.78	0.514	1.118	0.223	0.006	0.019	0.022	1.059	0.061	0.018	79.05
$\sigma_{relative}$ [%]	0.63	6.77	17.03	24.26	8.23	91.90	25.96	29.18	24.70	24.70	27.45	0.80

With an aluminium content of 95.13±0.6 wt.-% the sensor-based sorting reveals a high grade of enrichment within the light metal fraction. However, the contents of copper and zinc display a negative correlation to the aluminium content. This means the higher the concentration of Cu or Zn the lower is the Al content. This behaviour seems to be affected by the volatile character of the feedstock, especially by the variety of how these elements are incorporated within the feedstock. Concerning the melting yield a stable average of 79 wt.-% represent an elevated level of non-metallic contamination. Thus the metal yield can be increased by mechanical conditioning. So far different NaCl/KCl ratios in the salt do not influence the melting yield and the product alloy composition in a detectable way. Finally, a further refining of obtained product alloys is necessary in order to adjust marketable alloy composition, e.g. by dilution with technical pure Al or Al master alloys.

The high zinc concentration in the investigated heavy metal fraction leads to Zn burn-off. Therefore lab-scale trials with a premolten fayalite slag under standard atmosphere obviously are not promising. Hence the process has been modified in two steps; for the first step the temperature and process gas pressure (process gas = Ar) needed for the distillation of zinc is adjusted. The second step consists in further heating of the remaining feedstock up to 1200 °C in order to constitute a homogenous melt. Since this method respectively the experimental set-up is complex, only a few trials have been conducted. So far a quantitative or statistical evaluation is not considered yet. Nevertheless, there are a few qualitative statements which can be mentioned here. On the one hand vacuum distillation of zinc is possible, but the success of this thermal separation step highly depends on the amount of non-metallic contamination, which in particular affects the quality of vacuum reached in the loose bulk. On the other hand the aluminium content in the melting product of the distillation trials lies in the range of 50 to 60 wt.-%. This preliminary result implicates that further improvement of the upstream processing steps are mandatory.

5 Conclusion

The main goal of the VeMRec project with its holistic approach and broad consortium is the maximisation of nf-metal recovery from incineration ashes. To find the ideal intersection point between processing and metallurgy, a continuous and iterative process of improvement for the entire value chain is implicated. In this article first experiments are presented which have been performed with nf-metal concentrates of a particle size bandwidth 6.3 to 16 mm. The results of melting trials with the light metal fraction demonstrate that XRT sorting is a powerful technology of dry density separation of nf-metals. Nevertheless, the volatile character of nf-metal concentrates leads to a relatively low variation in product alloy composition which cannot be neglected for the further utilisation. Furthermore, the trials with heavy fraction emphasise the necessity of further investigations on different sorting set-ups regarding product composition and purity. Subsequent sorting steps of the heavy fraction for improved copper enrichment or even for the separation of different alloys (equivalent valid for light fractions) are optional. The correlation between mechanical material conditioning and melting yield in the downstream metallurgical treatment reveals another interdisciplinary area of research and development.

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