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TMS has forged cooperative agreements with several carefully selected organizations that actively work to benefit the materials science community. In this occasional series, JOM will provide an update on the activities of these organizations. This installment, by the Center for Resource Recovery & Recycling (CR^3), focuses on the different recycling options for electric arc furnace dust and shines a light on a promising new developing technology. The CR^3 is a research center established by Worcester Polytechnic Institute, Colorado School of Mines, and KU Leuven. More than 20 corporations, along with support from the U.S. National Science Foundation's Industry & University Cooperative Research Program, are sponsors of the center.

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Moving Towards Better Recycling Options for Electric Arc Furnace Dust

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When recycling steel scrap in an electric arc furnace, 15–18 kg of dust (EAFD) is generated for each ton of produced steel. This dust essentially is an oxidized mixture of the volatile elements present in the furnace (Zn, Pb, Cd, and halides) and small steel melt and slag particles (Fe, Cr, Ca, Si, Mg). Worldwide, 7.1 Mt of dust were produced in 2010,[1] a number that continues to rise due to increasing recycling volumes and application of galvanization. Since the dust contains the spinel franklinite ($ZnFe_2O_4$), recycling requires drastic treatment conditions to recover the zinc.

U.S. Environmental Protection Agency legislation against landfilling the dust has caused an increase in recycling rates since the late 1980s. However, nothing changed in the regions where landfilling has not been restricted. Due to the large amount of dust generation in those regions, only 40% of the total amount of generated dust is recycled. This leaves a large potential for improvement in zinc recycling.

Since more than 50% of all used zinc goes into galvanizing,[2] EAFD plays a key role in the life cycle of zinc. The growing awareness of depletion of metal reserves and increasing metal prices are becoming good motivators to start the treatment of the dust in favor of landfilling. In the regions where recycling rates were already good, these extra incentives resulted in a growing interest in the iron content of the dust for iron recovery.

A whole range of metallurgical technologies was developed to recycle the dust. So far, most of these have faced serious problems. For the hydro projects, the stability of the franklinite phase has always been a major issue. Since it does not dissolve under most leaching conditions, a maximum zinc leaching recovery of 70% has been observed.[3] Another issue of the hydrometallurgical processes is that they are unable to recover iron economically. With increasing interest of the industry to also recover the iron, the appeal of hydro for further development has been dwindling. High temperature metal recovery (HTMR)

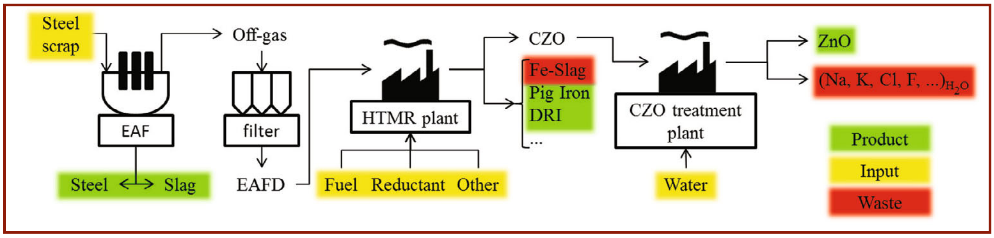

Figure 1. Traditional electric arc furnace dust treatment pathway.

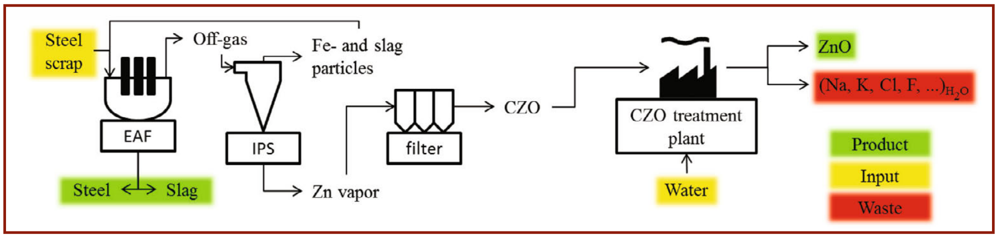

Figure 2. Alternative EAFD treatment pathway. Implementation of IPS could replace the need for an energy and resource intense HTMR process.

Table I. Overview of Currently Available Recycling Options for Electric Arc Furnace Dust

Process Name	Temperature	Furnace type Input	Products	Scale	Capacity	(kt/y)
Waelz Kiln[1,4]	1150–1200°C	Rotary kiln	Coal, lime/sand, natural gas, air	CZO, Fe-slag (waste)	Commercial	40–250
RHF[5] (low Zn EAFD)	1250–1300°C	Rotary hearth furnace	Coke, binder, natural gas	CZO, DRI/HBI	Commercial	100–300
RHF[5–9] (high Zn EAFD)	1250–1300°C	Rotary hearth furnace	Coke, binder, natural gas	CZO, DRI/HBI	Commercial*	200
Primus[10,11]	1000–1100°C	Multiple hearth furnace + EAF	Coal, air	CZO, pig iron	Commercial	100
Ausmelt[12–14]	1250–1300°C	Top Submerged Lance furnace	Coal, O_2-enriched air	CZO, Fe-slag (waste)	Commercial	100
ESRF[15,16]	1300–1500°C	EAF	Binder, air, electricity	CZO, Pig iron, and slag	Commercial	36
Submerged Plasma[17–19]	1300–1400°C	Submerged plasma reactor	Coke, natural gas, fluxes, air, electricity	CZO, Fe-slag (waste)	Commercial	40 – 60
PIZO[20–22]	1300–1500°C	Induction furnace	Coal, air, electricity	CZO, pig iron	Commercial	50
OxiCup[23]	1500–1600°C	Shaft furnace	Coke, scrap, bricks (waste + cement + C)	CZO, molten metal, and slag	Commercial	200 (dust and sludge)
Coke Packed Bed[24,25]	1500–1600°C	Shaft furnace	Coke, fluxes, O_2-enriched air	CZO, molten metal, and slag	Pilot Plant	10
LAMS[26,27]	900-1100°C	—	$CaCO_3$ + heat	CZO, $Ca_2Fe_2O_5$ for use in blast furnace	Lab-scale	—
EAFD+PVC pellets[28,29]	800°C	—	PVC + heat	$ZnCl_2$, Fe+C pellets	Lab-scale	—

* First large proof-of-concept plant is still ramping up to full production.

processes, on the other hand, have known a certain degree of success. Currently, the Waelz kiln process is recognized as the best available technique to handle the dust. It is used to treat roughly 80% of all recycled EAFD. Traditionally, the recycling of EAFD can be seen as described in Fig. 1. As an alternative to the Waelz kiln process, a variety of different technologies have been developed. These use different furnace designs, working temperatures, reducing agents, additives, etc. An overview of these alternatives can be found in Table I. Most of these processes produce a crude zinc oxide (CZO) product that requires some further processing (halide removal) before it can be used by zinc smelters.

In a previous exergy efficiency analysis study for CR[3] the two most applied technologies (Waelz kiln and RHF) have been compared.[30] Starting from the EAF off-gas, the optimized Waelz kiln process (Table I, first entry) underperforms compared to the RHF process as described by ZincOx (Table I, third entry).

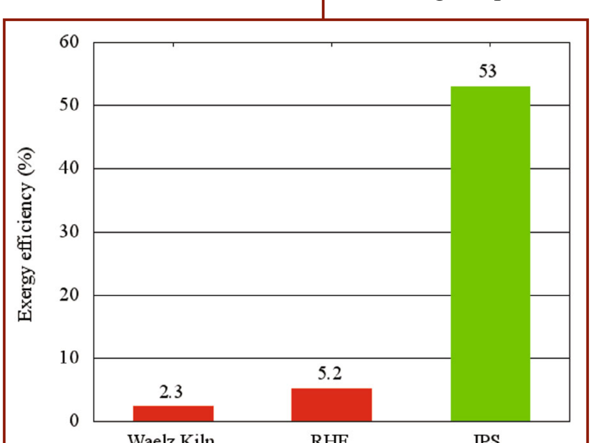

Figure 3. Exergy efficiencies of the Waelz kiln, RHF, and IPS technologies.

However, this study clearly indicated that HTMR processes might not be the ultimate solution for EAFD recycling since their total exergy efficiencies are rather low. The study also included calculations for a new, conceptual alternative to HTMR processes: treatment of the EAF off-gas in the EAF plant itself to prevent the formation of EAFD and the need for its costly recycling processes.

Recently, N. Ma proposed a radical new approach, the In-Process Separation (IPS) technology,[31,32] in which zinc is removed from the EAF off-gas before it can react with iron-containing particles to form the $ZnFe_2O_4$ phase in the combustion chamber (Fig. 2). The dust collected in the baghouse filters can then be sent directly to the CZO treatment plant as it will no longer contain Fe. Depending on the atmospheric conditions in the off-gas treatment system, iron or iron oxide particles can be returned to the EAF. Thermodynamically, this treatment step drastically outperforms any HTMR process since it has an exergy efficiency of 53% (Fig. 3) while the exergy efficiency of the current EAF off-gas system is 24%. Further treatment of the dust in a HTMR process will only reduce this value. Economically, the technology would transform the traditional EAF off-gas treatment system from a waste collecting part of the plant to a zero-waste valuable by-product producing segment.

Recognizing the technology's potential impact on EAFD recycling, CR³ has a project running to experimentally evaluate the feasibility of the IPS technology. The major drawback of this new technology is that it requires implementation in each individual EAF plant. Unlike traditional HTMR processes, the starting product cannot be collected from a larger area to treat a lot of dust simultaneously. All plants operating without the IPS technology will continue producing EAFD, maintaining the need for HTMR plants.

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