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# Past and current R & D activities at the IME in Aachen

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## Past and current R & D activities at the IME in Aachen

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The IME is a department of the Technical University Aachen, Germany (Faculty of Georesources and Materials Engineering) dealing with research and education in the field of non-ferrous process metallurgy, such as process development for metallic materials, recycling metallurgy, vacuum and inert gas metallurgy, electrolysis and electroplating and thermo-chemical and kinetic process modeling.

Two 96-kW laboratory Arc Furnaces (closed and open version) each with a volume of 5 l and a 500 kW (AC/DC) semi-pilot Arc Furnace with a volume of 100 l are available at the IME. This furnace is unique in Europe and allows a variety of different research possibilities due to its adjustable operation principles.

The main research area at IME in the context of EAF/SAF activities are steel recycling (conventional and combined with the reduction work), recycling of non-ferrous scrap (catalysts, batteries, Fe/Cu-mixed scrap, slags) as well as the treatment of non-metallic intermediates (copper, Pb/Zn, precious metals, dusts, ashes, sludge).

As an example of each field a project is presented in the following. In all cases theoretical investigations like thermo-chemical calculations for the assessment of equilibrium conditions under different parameters are done before start-up of the experimental work.

The project "Steel recycling to cast iron" aimed at replacing the use of FeSi by the reduction of quartz in addition to the use of low-price carbon and other advantages concerning energy consumption. After the successful lab scale experiments, the corresponding experiments were conducted in the semi-pilot Arc Furnace at the IME. The results were so promising that a pilot 5-MVA and later a furnace plant for producing Si-containing cast iron were built in the USA.

A project in the field of recycling is the reprocessing of primary batteries. It is motivated by the need to avoid the contamination of water and soil by depositing. It could be demonstrated in melting test series in laboratory and semi-pilot Electric Arc Furnaces that pre-pyrolyzed batteries are melted and after an adequate reduction work an FeMn phase and a Zn-rich dust could be produced.

A project in the field of slag treatment dealt with lead-zinc slags from the pyrometallurgical Pb- and Zn-extraction with approx. 11 % Zn and 1 to 9 % Pb. It is the aim to reduce the Zn-content to below 1 % and the Pb-content to below 0.1 % due to reasons of environmental

protection and, at the same time, to extract Pb and Zn as metals or flue dust. After the test series in the laboratory and semi-pilot SAF, the desired contents in the final slag could be achieved by forming a Zn- and Pb-rich flue dust and a separate Pb-phase. The equilibrium contents in the slag calculated beforehand could be approximately achieved.

The potential of future SAF/EAF-research can be found in various fields e. g. the reduction of FeCr from steel scrap and chromite, the treatment of diesel particle filters and catalysts for extracting precious metals, the optimization of melt reduction of customary titanium slags, processing of metal-containing dusts by hollow electrode system-technology in the SAF/EAF, reprocessing of waste dust and waelz slags, the extension of the injection technology, the recycling of Si-waver scraps and the recycling of NiMH and Li-ion batteries etc.

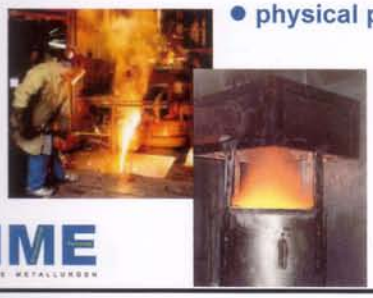
In order to meet these demands of this versatile research, the semi-pilot SAF/EAF at the IME today undergoes various upgrades, such as

- the vibration feeder (200 l hopper) for furnace
- new vibration feeder (100 l hopper) for hollow electrode
- replacement of the electricity supply (new: 630 kVA)
- replacement of the furnace control system
- extension of the installed sensor technology

The good cooperation between SMS Demag and the IME in the field of exploring new techniques or optimizing existing processes will facilitate further interesting research work in the future.

## IME Research Fields and Working Groups

- vacuum- and inert-gas metallurgy
- melt treatment and purification
- hydrometallurgy and electrolysis
- recycling processes
- thermochemical and kinetic process modeling
- physical properties of molten slags and metals



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## IME furnaces (1)

| laboratory furnace | IME |
|---|---|
| capacity: | 96 kVA |
| tapping capacity: | 15 kg |
| furnace diameter: | 0,2 m |
| furnace height: | 0,5 m |
| electrode diameter: | 50 mm |

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## IME furnaces (2)

| laboratory furnace | IME |
|---|---|
| capacity: | 0,5 MVA |
| tapping: | up to 450 kg |
| furnace diameter: | 0,6 m |
| furnace height: | 0,8 m |
| electrode diameter: | 150 mm |

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## Main Focus at IME for EAF research: Recycling

- Iron recycling
  - Convent. steel
  - Combined melting/reducing
- Recycling of non-ferrous scrap
  - Katas scrap
  - Consumer battery scrap
  - CU/Fe mix scrap
- Treatment of non-ferrous by-products
  - Copper
  - Pb/Zn-slags
  - Precious metal (Pt)
  - Dusts/ashes/sludges

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## Steel recycling to cast iron (1)

Objectives

- FeSi-substitution by the reduction of quartz
- use of low-price carbon
- slag-free process
- complete off-gas control
- preheating in the shaft

Aim

- conduction of continuous running process in IME-furnace
- control of Si- and C-content in cast iron depending on input composition

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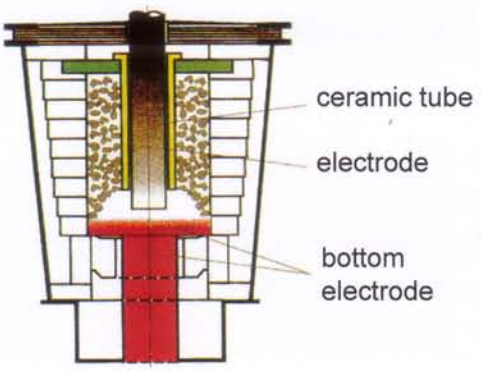
## Steel recycling to cast iron (2)

Examinations at the IME:

- pre-test runs in laboratory electric arc furnace
- melting tests in pilot electric arc furnace

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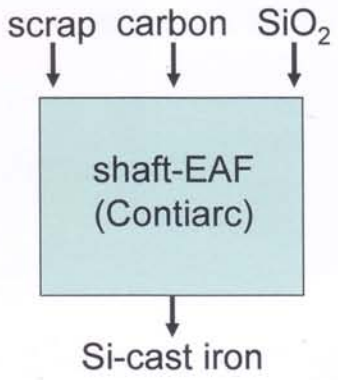
## Steel recycling to cast iron (3)

Result:

- continuous process in special shaft furnace possible
- cast iron quality continuously 14 % Si
  3,5% C

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## Recycling of primary batteries (1)

Problems:

- possible contamination of water and soil by heavy metals
- battery directive 1998: return obligation of the consumers; obligation of the dealers and municipality to take back the batteries
- avoidance of depositing

Objective:

melting of pre-pyrolyzed batteries in the electric arc furnace by formation of FeMn- and Zn-gas

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## Recycling of primary batteries (2)

Test run in semi-pilot furnace:

- about 200 kg primary batteries per experiment were melted
- slags with different compositions were tested
- melt temperature about 1500 °C
- experimental time: 2 hrs. per exp.
- kind of process: carbothermic reduction

| | |
|---|---|
| $MnO_2$: | 22 – 38 % |
| Fe: | 14 – 26 % |
| Zn: | 5 – 29 % |
| C: | 4 - 8 % |
| Cu: | 0 - 3 % |
| electrolyte: | 5 – 23 % |
| plastic: | 3 – 11 % |

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## Recycling of primary batteries (3)

Results of test runs in semi-pilot furnace:

- 50% of Mn-input and nearly 100 % of Fe-input is recovered in the metal phase FeMn
- FeMn contains up to 50 % Mn
- nearly 100 % of Zn input is recovered in fluedust
- slag with up to 50 % Mn can be used in FeSi production

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## Treatment of lead-zinc slags (1)

lead-zinc-slag:

- source: pyrometallurgical lead- and zinc production
- 10 – 12 % zinc
- 1 – 9 % lead
- FeO, $Fe_2O_3$, $Fe_{met}$, $SiO_2$, CaO, MgO, $Al_2O_3$, (S)

research aims:

- reducing the lead content to < 0,1 %
- reducing the zinc content to < 1 %
- extracting lead and zinc as metal or flue dust
- avoiding environmental damage
- utilization of slags in e. g. road and dyke construction

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## Treatment of lead-zinc slags (2)

- Chemical, mineralogical and DTA-analysis for characterization of two Pb-Zn slags
- Thermo chemical calculations for the assessment of equilibrium conditions
- Test series in laboratory scale SAF for the investigation of favorable parameters for the slag treatment and first assessment of possible products
- Test series in pilot scale SAF for the realization of batch wise slag treatment with assessment of gainable products, setting up of mass balances and evaluation of products
- Utilization of hollow electrode system in both laboratory and pilot scale tests for charging of coke, in near future as well utilization of injection technology

View of the electrode submerged in the bath

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## Treatment of lead-zinc slags (3)

Results:

- generated products:
  Zn- and Pb-free slag,
  ZnO- and PbO-containing flue dust,
  metallic lead (to some extent)
- final slag: < 0,1 % Pb and < 1 % Zn accomplished
- obtained Zn- and Pb-contents in the slag are in good agreement with calculated thermo chemical equilibria
- advantages of the SAF: low off gas volume, low coke consumption, production of utilizable flue dust and metal possible

Future prospects:

- utilization of injection technology for coke input
- evaluation of the economy of SAF treatment for Pb-Zn slags

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## Possible future arc-furnace research

- reduction of FeCr from steel scrap and chromite
- DPF and catalyst for the recovery of noble metals, optimization of the melt reduction of customary titanium slag
- processing of metal-containing dusts with HES in the electric furnace
- reprocessing of waste rust and waelz slag
- extension of the injection technology
- recycling of Si-waver scraps
- transfer of know-how to NiMH and Li Ion
- ...

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